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Alexandra falls on Hay river; height 105 feet. (Page 28.)

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GEOLOGICAL SURVEY

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MEMOIR 108

No. 92, GEOLOGICAL SERIES

# The Mackenzie River Basin

(REVISED EDITION)

BY

Charles Camsell and Wyatt Malcolm



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OTTAWA

THOMAS MULVEY

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# The Mackenzie River Basin

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## GENERAL STATEMENT

The basin of Mackenzie river and its tributaries has received considerable attention in recent years. It is a section of country through which settlement is gradually extending northward, and through which agricultural development will probably be limited in its northward movement by climatic conditions only. As settlement progresses transportation lines are opened up, and increased interest is taken in all the economic resources of the region. Information about this region is very limited, as the explorations that have been carried on since Alexander Mackenzie descended in 1789 the great river that bears his name, have been confined almost wholly to the principal water routes. It is the purpose of this compilation to present a concise statement of the present knowledge of its economic possibilities, particular attention being given to the geological features and possible mineral resources. To this compilation Charles Camsell, one of the writers, contributes much information acquired by long residence in and wide exploration throughout, the Mackenzie River basin.

## LOCATION AND AREA

The basin of Mackenzie river occupies the northwestern part of the continent of North America and includes within its area the northern parts of the provinces of British Columbia, Alberta, and Saskatchewan, the western part of the Northwest Territories, and parts of southeastern and northeastern Yukon. It crosses 16 degrees of latitude between the 53rd and the 69th parallels, and 36 degrees of longitude between the 104th and the 140th meridians.

The greater part of the basin lies in what is known as the Great Plains of North America, but a considerable portion is also included within the Laurentian Plateau region on the east and about an equal area within the Cordilleran region on the west.

The total area of the Mackenzie basin is about 682,000 square miles or somewhat more than one-fifth of the area of Canada exclusive of the islands in the Arctic ocean. Water, as lakes, covers a very large part of this area, and although many large lakes of the region are still unexplored and unmapped it is estimated that the water area cannot be less than about 40,000 square miles.

The total length of the river from the headwaters of Finlay river to the Arctic ocean has not yet been accurately measured, but it is estimated to be 2,525 miles.

The Mackenzie River system ranks as one of the eight great river systems of the earth. On the North American continent it is exceeded in length and drainage area only by the Mississippi river. It has a slightly greater length and larger area than the St. Lawrence.

The following table of lengths and areas, taken mainly from the Atlas of Canada, will serve to give an idea of the importance of the Mackenzie river relative to the other large river systems of the continent of North America.

	Length, miles	Area, sq. miles
Mississippi (to head of Missouri).....	4,220	1,244,000
Mackenzie (to head of Finlay).....	2,525	682,000
St. Lawrence (from Pt. de Monts to head of St. Louis).....	1,900	498,500
Yukon (to head of Nisutlin).....	1,765	330,000
Nelson (to head of Bow).....	1,660	370,800
Colorado (to head of Green).....	2,200	225,000
Columbia.....	1,150	250,000

## HISTORY

The earliest explorations in the basin of the Mackenzie were made in the latter part of the eighteenth century. Samuel Hearne of the Hudson's Bay Company set out in December, 1770, from Fort Prince of Wales at the mouth of Churchill river on a journey to Coppermine river to investigate the copper deposits of that region. He reached the river and followed it to its mouth. On his return he took a more westerly course than that followed on his northward journey, crossed Great Slave lake, and ascended Slave river some distance. From this river he travelled eastward and arrived at Fort Prince of Wales at the end of June, 1772.

The first white man to appear on Athabaska river was Peter Pond. His route to the Athabaska lay by way of Churchill river, Ile à la Crosse lake, Buffalo lake, Methy river, Methy lake, Methy portage, and Clearwater river, a route that was used for many years as the readiest means of access to the Mackenzie basin. In 1778 he descended the Athabaska and founded a fort known as the "Old Establishment" about 30 miles above its mouth. He was also, evidently, the first white man to reach the shores of lake Athabaska. In 1786 Pond sent Laurent Leroux and Cuthbert Grant to build a fort on Great Slave lake; these being the first white men, with the exception of Samuel Hearne, to visit this lake. The post was built at the eastern mouth of Slave river.<sup>1</sup>

Philip Turner carried on explorations in this part of the country in 1790-92 and made careful surveys of Athabaska river below the mouth of Clearwater, of Athabaska lake, of Slave river, and of a small portion of the south shore of Great Slave lake.<sup>2</sup>

In 1788, Fort Chipewyan was built on the south shore of lake Athabaska on what is now known as Old Fort point. From this point Alexander Mackenzie set out in the spring of 1789 to explore the river that drains Great Slave lake. In spite of repeated warnings from natives as to the danger of the undertaking he pushed his way with indomitable energy to the mouth of the river and returned to Fort Chipewyan after an absence of only one hundred and two days, accomplishing one of the "most remarkable exploits in the history of inland discovery, whether regarded in the light of the results achieved, or of the time taken to cover a journey of nearly three thousand miles."

<sup>1</sup> Burpee, Lawrence J., "Search for the western sea," p. 416.

<sup>2</sup> Burpee, Lawrence J., "Search for the western sea," p. 172.

In 1792 Mackenzie ascended Peace river. He passed a post which had been built under his instructions in 1788 and up to which the river had already been surveyed on behalf of the North-West Company, and continued upward to a point 6 miles above the mouth of Smoky river. After spending the winter at this point he set out in the spring of 1793 on that memorable voyage of discovery that was to carry him to the Pacific coast, ascending the Peace, the upper waters of which had never yet been explored.

A complete survey of Athabaska river appears to have been made by David Thompson, one of the greatest of Canadian explorers. In 1799 he descended Pembina river. On April 25 he reached the junction of the Pembina with the Athabaska, which he surveyed to the mouth of Lesser Slave Lake river. He then surveyed Lesser Slave Lake river to Lesser Slave lake, and returning to the Athabaska, travelled downstream to the mouth of the Clearwater.<sup>1</sup> In the spring of 1804 he surveyed the Athabaska from its mouth to the Clearwater and in 1810 explored a portion of the upper course of the river.

Among the early explorations that proved most fruitful in results were the two expeditions conducted by Captain (afterwards Sir) John Franklin. Accompanied by Dr. John Richardson, George Back, and Robert Hood, Franklin left Old Fort Providence on the north arm of Great Slave lake in 1820 on an overland trip to Coppermine river and the Arctic coast. He spent the winter near Winter lake erecting a small building which was named Fort Enterprise. In 1821 he descended the Coppermine and explored the Arctic coast eastward as far as Turnagain point. Returning he ascended Hood river as far as Wilberforce falls and from that point travelled overland to Fort Enterprise, reaching Fort Providence in December, after enduring indescribable hardships and suffering.

A few years later Franklin was placed in command of an expedition sent out to explore the Arctic coast west of Coppermine river. After spending the winter of 1825-6 on Great Bear lake the expedition descended the Mackenzie to the head of the delta. Here it divided, and Franklin, accompanied by Back, followed the western branch and explored the coast to Gwydyr bay near point Beechey. Richardson, with a young naval officer named Kendall, descended the eastern branch of the river and surveyed the coast eastward as far as Coppermine river. He ascended this river some distance and returned on September 1 to the fort on Great Bear lake where the winter of 1825-6 had been spent. Franklin reached the fort on September 21.

During the autumn of 1833 George Back explored a number of lakes lying to the northeast of Great Slave lake and in 1834 followed Great Fish river (now Backs river) to its mouth and explored a portion of the coast. Thomas Simpson and Peter Warren Dease, officers of the Hudson's Bay Company, carried out important explorations on the Arctic coast to the west of Mackenzie river in 1837 and to the east of the Coppermine in 1838 and 1839. In 1848 Dr. John Richardson again descended the Mackenzie and followed the coast to Coppermine river. Mention may be made also of the expedition of James Anderson and Stewart of the Hudson's Bay Company down Backs river, and to that of Roderick MacFarlane in the Anderson River region.

Explorations in the country to the north of Great Bear lake and between that lake and Great Slave lake were made by Emile Petitot, a missionary who was stationed in the Mackenzie basin for a number of years. More recent explorers are Warburton Pike and David T. Hanbury.

<sup>1</sup> Tyrrell, J. B., David Thompson's narrative of his explorations in western America, p. LXXIX.

Important surveys and explorations have been made by members of the staff of the Department of the Interior, Ottawa, who made observations on the economic resources of the sections of country traversed. Our more intimate knowledge, however, of the geological features and mineral possibilities, has been obtained from investigations made by field officers of the Geological Survey, Canada.

Of the exploratory surveys carried out by the Department of the Interior those made by William Ogilvie are among the most important. During the summer of 1888 he entered Mackenzie basin from Yukon by way of Porcupine river, Bell river, McDougall pass, and Rat river, a tributary of the Peel. He carried his survey up Mackenzie river, Great Slave lake, and Slave river to lake Athabaska, making observations on the natural features of the country through which he passed. He had already made surveys on the Athabaska and Peace rivers in 1884. In 1891 he ascended the Liard and surveyed Fort Nelson river, afterwards crossing to Fort St. John on Peace river. Explorations in the country to the east of Great Slave lake were made for the Department of the Interior in 1900 by J. W. Tyrrell; and the various surveyors who have run lines for the Department in the Athabaska and Peace River regions have reported on the resources of those districts.

Reconnaissance surveys have been made by the Geological Survey along the principal water routes.

In 1875 Alfred R. C. Selwyn explored Parsnip river and Peace river to the mouth of Smoky river and ascended Pine River South as far as Table mountain. John Macoun who accompanied him on this expedition continued the exploration down the Peace and up Athabaska river to the Clearwater returning by way of Methy portage, Fort Carlton, and Fort Garry (Winnipeg).

In 1879 George M. Dawson made an exploration through northern British Columbia and Peace River district to Edmonton. Entering Peace River district by way of Pine River pass he descended Pine River South to its lower forks and from this point journeyed overland to Dunvegan. Going south from Dunvegan he explored part of Wapiti river, descended Smoky river to its mouth, and returned to Dunvegan. From this point he went overland in a southeast direction to Athabaska river, descended this river to Athabaska Landing, and ended his survey at Edmonton. R. G. McConnell, who was with Dawson on this expedition, travelled from Dunvegan by the north shore of Lesser Slave lake to old Fort Assiniboine and to Edmonton. McConnell also descended Athabaska river from Athabaska Landing to La Biche river, and then made a traverse of the country by way of lac La Biche, Whitefish lake, and Goodfish lake to Victoria (now Pakan) on the Saskatchewan.

Robert Bell in 1882 made a geological examination of lac La Biche, La Biche river, Athabaska river below La Biche river, Clearwater river, and Methy portage.

The member of the Geological Survey staff who has carried on most extensive explorations in the Mackenzie basin and to whom we are most indebted for our knowledge of the geology is R. G. McConnell. In 1887 he descended Liard river to its mouth and at Simpson took passage on the Hudson's Bay Company's steamer for Fort Smith on Slave river. The remainder of the season was spent in examining the geology of Slave river, Salt river, Hay river, and of the western end of Great Slave lake. Winter was spent at Providence and from here rough traverses were made to lake Bistchô, Fort Rae, and other points. In the summer

of 1888 he descended the Mackenzie to the Peel which he ascended to Fort McPherson. After making an exploratory trip up Rat river he crossed to Lapierre house by way of Peel River portage, descended Porcupine river, and carried on explorations in Yukon.

In 1889 and 1890 McConnell explored the country between Athabaska and Peace rivers north of Lesser Slave lake. A careful examination was made of the geology along the Athabaska from Little Slave river to its mouth and along the Peace from Smoky river to Mikkwa river, and the more important tributaries were ascended.

The south shore of lake Athabaska was explored by D. B. Dowling in 1892, and the north shore by J. B. Tyrrell in 1892 and 1893. Cree river and the system of lakes and rivers to the east of lake Athabaska were also explored by Tyrrell and Dowling.

During the summer of 1899 explorations on Great Slave lake were conducted by Robert Bell and his assistant J. M. Bell. The latter remained at Resolution during the winter of 1899-1900 and in 1900 explored Great Bear river and the north and east shores of Great Bear lake. He made a traverse to Coppermine river, and returning to Great Bear lake reached Slave lake by a canoe route formed by a series of lakes and streams between McTavish bay and the north arm of Great Slave lake.

During the summer of 1902, Charles Camsell carried on explorations in the country to the west of Slave river, making an overland traverse southwest from Fort Smith to Salt river and Little Buffalo river, and following Jackfish river to the Peace. In 1905 he made a reconnaissance survey of Wind and Peel rivers. Entering Wind river by Nash creek he descended it to its confluence with the Peel which was descended to below mount Goodenough.

In 1907-8 Joseph Keele made surveys on the Pelly, Ross, and Gravel rivers, descending the last-named from its source to its junction with the Mackenzie.

Parts of the field seasons of 1913, 1914, and 1915 were spent by S. C. Ells in an investigation of the bituminous sands of Athabaska river. During the summer of 1914 Charles Camsell explored a section of country along Tazin and Taltson rivers between Athabaska and Great Slave lakes. In the same year a study was made by F. J. Alcock of the geology of a portion of the north shore of lake Athabaska. Further investigations were carried on by Camsell in 1915, by Camsell, Alcock, McLearn, Cameron, and MacVicar in 1916, and by Kindle, McLearn, and Cameron in 1917.

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## GENERAL CHARACTER OF THE DISTRICT

## TOPOGRAPHY

*General Statement*

The Mackenzie basin, covering as it does some 682,000 square miles of territory in northwestern Canada, necessarily embraces a great variety of topographic forms. Its longer axis, about 1,350 miles in length, conforms in its direction to the trend of the main physiographical features and strikes northwestward. In width it ranges from 100 miles at the mouth of the river, to 900 miles near the centre of the basin.

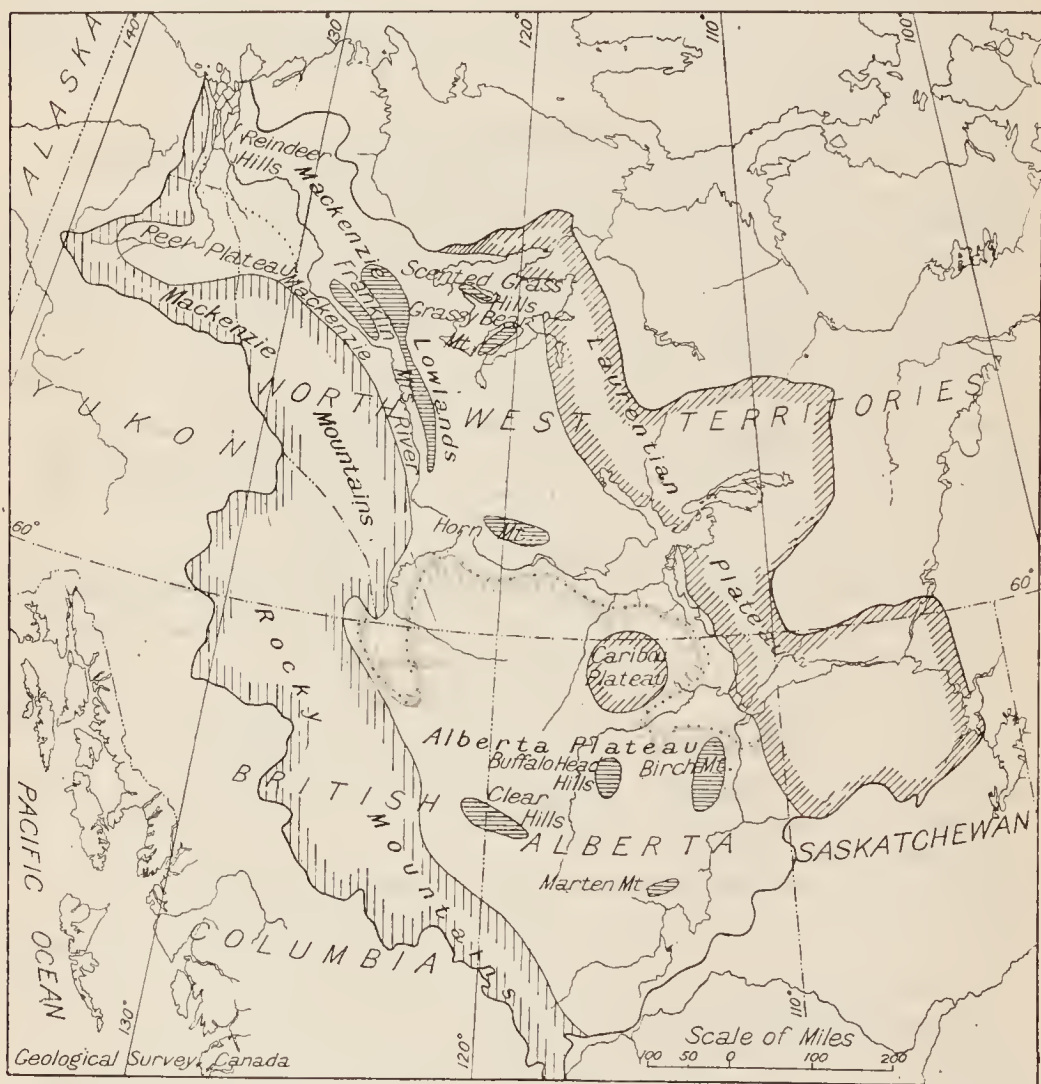


Figure 1: Diagram of the Mackenzie River basin, and its main physiographical features.

It includes within these boundaries three main physiographic provinces (Figure 1) each of which runs almost the whole length of the basin and has characteristics which sharply distinguish it from the adjacent provinces. The

three provinces are: a rugged, mountainous highland on the west, known as the Cordilleran region, which is a continuation of the mountainous region that forms the backbone of the North American continent; a relatively more subdued, but rocky, and partly treeless plateau in the east is part of the Laurentian plateau that almost encircles Hudson bay; and between these two a broad, almost level, forested plain through which the trunk stream flows northwestward to the Arctic ocean, fed on the one hand by swift-flowing streams from the Cordilleran region and on the other hand from the numberless lakes of the plateau to the east. The last is the northward continuation of the Great Central plain of North America, and in this the Mackenzie river occupies the same position and performs the same functions that the Mississippi river does in the south as it flows towards the gulf of Mexico.

The drainage area of the Mackenzie river is a great basin, its western side dipping somewhat steeply northeastward and its eastern side sloping more gently westward to a central depression; and the whole tilted with a long easy slope northwestward to the Arctic ocean. The degree of slope of the central depression towards the northwest from the divide between the Saskatchewan river and the Mackenzie to the Arctic ocean is about 2 feet to the mile. This slope, however, is not uniform throughout, for besides the irregular hills and mountain ranges which rise out of the lowland there are north facing escarpments which interrupt and break the grades of the streams, and large local areas of depression in which the water accumulates to form the great lakes of this northern region. The largest of these lakes are Great Bear, Great Slave, and Athabaska, all of which rank among the large freshwater lakes of the world. The Laurentian Plateau region also holds innumerable lakes of smaller size on its uneven pitted surface.

#### *Laurentian Plateau*

The great physiographic province known as the Laurentian plateau (Plate II A), which covers such a great part of northeastern and northern Canada on both sides of Hudson bay, extends for some distance into the basin of Mackenzie river and occupies a strip along its eastern edge about 80 to 280 miles wide extending over a length of 800 miles from the height of land at the south to the northern shores of Great Bear lake.

The western border of this province, where it abuts against the central plain, is a fairly well-defined line marked by the contact between the Precambrian crystalline or metamorphic rocks and the flat-lying Palaeozoic sedimentary rocks. This line of contact enters the Mackenzie basin from the south at Methy portage on Clearwater river in longitude 110 degrees west. Running northwesterly from there it passes the east end of Athabaska lake and follows the valley of Slave river to Great Slave lake. Crossing Great Slave lake in a northwesterly direction it runs from the northern end of the north arm of the lake to the southern point of McTavish bay on Great Bear lake and continues across the lake in the same direction until it passes outside the limits of the basin north of Smith bay. East of this line and extending far beyond the limits of the Mackenzie basin towards Hudson bay is the Laurentian Plateau province.

South of lake Athabaska there is apparently no topographic break to mark the change from the Laurentian plateau to the Great Central plain, the one

merging gradually into the other. Between Athabaska and Great Slave lakes there is also no marked change of slope along the contact of the two provinces because of the thick deposits of alluvium that have been spread along that contact by the Peace and Slave rivers. North of Great Slave lake, however, the contact appears to be well defined by a low but abrupt escarpment, facing eastward and built of the flat-lying sedimentary rocks that underlie the Great Central plain. Whether or not this escarpment is continuous is impossible to say at present, but from the canoe route between Great Slave and Great Bear lakes it was noted by J. M. Bell<sup>1</sup> and Preble at a number of points. North of Great Bear lake enough information is not available to define the nature of the contact between the two provinces.

The physical features of this province are typical of the whole Laurentian plateau generally. When viewed broadly the topography is that of a broad plain sloping gradually to the west and north with a gradient towards the great lake depressions which rarely exceeds 6 or 8 feet to the mile. Here and there residual round-topped hills or monadnocks rise a few hundred feet above the general level, but these hills are not as a rule connected into definite ranges nor aligned in any particular direction. In detail, however, the plateau is very irregular, broken, and rocky, with an uneven hummocky or mammillated surface (Plate II A).

The surface of the plateau is nowhere broken by any prominent ranges of hills and the vertical relief is nowhere so great as that which obtains in the Cordilleran province. The greatest relief is found on the shores of the great lakes where it reaches a maximum of about 1,000 feet. On the north shore of Athabaska lake at Black bay a group of irregular, round-topped hills rises 800 feet above the level of the lake<sup>2</sup>, and on the northeast end of Great Slave lake, R. Bell<sup>3</sup> describes hills of granite and gneiss rising "as a sea of half-rounded hummocks to a general height of nearly 1,000 feet all along the northwest side of this part of the lake and also around the northeastern extremity." Again, on the eastern shore of McTavish bay on Great Bear lake, steep cliffs rise abruptly from the lake shore to heights of 600 and 700 feet, and a few miles inland they reach a maximum of about 1,000 feet.<sup>4</sup>

Little is known of the character of the Laurentian Plateau province inland from the shores of the great lakes, except along a few canoe routes that have been traversed by Hearne, Franklin, Petitot, Tyrrell, Bell, Preble, Camsell, and a few others. From reports of these men it appears that the whole country is of a generally uniform level rising as a rule not more than 200 feet above the adjacent stream or lake levels and only at wide intervals is the evenness of the sky-line broken by any outstanding eminences. Instances of such eminences are, however, recorded by J. M. Bell<sup>5</sup> and E. A. Preble<sup>6</sup> in the country between Great Slave and Great Bear lakes where isolated peaks of conical or rounded outline rise as high as 1,000 feet above the level of the adjacent lakes. These higher hills are invariably composed of solid rock and usually of the harder igneous varieties; but lower hills of glacial origin and composed of sand, gravel, or boulders are described by J. B. Tyrrell<sup>7</sup>, in the region southeast of Athabaska lake. Such hills, however, rarely exceed 200 feet in height.

<sup>1</sup>Geol. Surv., Can., vol. XII, p. 20 et seq.

<sup>2</sup>Camsell, Charles, Geol. Surv., Can., Sum. Rept., 1914, p. 57.

<sup>3</sup>Bell, R., Geol. Surv., Can., vol. XII, 1899, p. 106 A.

<sup>4</sup>Bell, J. M., Geol. Surv., Can., vol. XII, 1899, p. 18 C.

<sup>5</sup>Geol. Surv., Can., vol. XII, 1899, p. 23 C.

<sup>6</sup>North American fauna, No. 27, U.S. Dept. of Agric., 1903, p. 114 et seq.

<sup>7</sup>Geol. Surv., Can., vol. VIII, 1895, pt. D.

Throughout the whole 800 miles of Laurentian plateau lying within the basin of Mackenzie river the higher points show only slight differences in their altitudes above sea-level. For example, the maximum altitudes at Crec and Wollaston lakes in the southeast end of the basin are given by Tyrrell and Dowling as about 1,650 feet. On the north shore of Athabaska lake they are 1,490 feet, on Great Slave lake 1,520 feet, on the divide between Great Slave and Great Bear lakes about 1,700 feet, and on the east of Great Bear lake between 1,300 and 1,400 feet above sea-level. Taking the lower levels of the plateau, however, there is a much greater difference in altitude between the plateau at the southeast end and that at Great Bear lake. The difference here is about 1,200 feet, giving an average slope to the whole region of about 1.5 feet to the mile in a northwesterly direction.

The Laurentian Plateau portion of the Mackenzie basin is essentially a lake country, and its surface is covered with thousands of lakes of all sizes, ranging from mere ponds to lakes hundreds of square miles in extent. So numerous are these lakes and so rocky and irregular the country between them that the only method of travel used by the natives or travellers in summer in this region is by canoe. By portaging from one lake to the other it is possible to travel by canoe in almost any direction required, although the only routes in regular use are those leading from the trading posts to the hunting grounds or fishing resorts of the Indians.

The lakes are almost invariably shallow rock basins with smooth rocky shores and comparatively few beaches of sand, gravel, or boulders. They are usually very irregular in outline and their shape and alignment have been determined partly by the structure and composition of the rocks in which they lie and partly by the direction of movement of the glacial ice-sheet. Long continued decomposition of the bedrock of the plateau region and subsequent removal of the decomposed surface by continental glaciation are the chief causes in the production of a pitted, mammillated surface favourable to the accumulation of water as lakes.

Owing to the peculiar character of the surface of the plateau and the relatively short time that has elapsed since this character was developed, the rivers flowing through the plateau have no well-defined valleys nor have they evenly graded profiles. They are characterized rather by a succession of level stretches of river or lakes separated from each other by falls or strong rapids. Frequently they are merely a succession of lakes joined to each other by narrow, gorge-like openings at which falls or rapids occur which interrupt navigation. Their courses are very erratic and are frequently dependent on chance irregularities of the bedrock floor. In consequence, none of them in the plateau is navigable without interruption for any great distance, and in travelling on them portages have frequently to be made. They carry practically no material in suspension, for there is very little loose material on the surface of the plateau to transport and what they do pick up is quickly deposited again in the lakes through which they flow.

All the rivers of the plateau region drain to one or the other of the three great depressions, Athabaska, Great Slave, or Great Bear lakes, and owing to their peculiar characteristics, namely, lakes and waterfalls, they are excellent streams for the development of water powers.

The Laurentian plateau in the Mackenzie basin has as a rule little or no mantle of soil or other loose material covering its bedrock (Plate II A), and

there does not appear to be any large portion of it that would be available for agricultural purposes even if the climate were suitable. A very large proportion of the region has a rocky surface. Boulder clay is found frequently filling depressions on the surface and here and there occur sand-plains or other accumulations of glacial drift. The whole region has been subjected to intense glacial erosion by which the surface has been worn down to the live rock and denuded of its loose material which has been carried westward and deposited in the lowland portion of the basin. South of Athabaska lake is a large area underlain by horizontally bedded sandstone which on decomposition forms wide plains of sand or gently rounded hills and ridges wooded with banksian pine.

In spite of its lack of soil, however, almost the whole region is wooded, though sparsely, with a forest of spruce, banksian pine, tamarack, poplar, birch, or willows. This forest becomes thinner towards the eastern and northern edge of the basin and disappears entirely north of the east end of Great Slave lake in the basins of Clinton-Colden, Aylmer, and MacKay lakes. This is the only part of the Mackenzie basin included within the great unforested region of northern Canada known as the Barren lands.

#### *Cordilleran Region*

On the western border of the Mackenzie basin and extending throughout its whole length is a lofty mountainous region constituting a part of the North American Cordillera. It forms a belt varying in width from 20 to 200 miles extending from the foothills which border the central lowlands to the height of land separating the Mackenzie waters from those which drain westward to the Pacific. The tributaries of the Mackenzie cut deeply into the ranges which constitute this region and two of them, the Liard and Peace rivers, cut right through, drawing much of their water from the western or back slopes of the ranges and from the plateau region lying to the west of them. This memoir, however, is not concerned with that portion of the Mackenzie basin lying west of the summit of the Rocky mountains which is drained by the upper waters of the Peace and Liard rivers. The Cordilleran province of the Mackenzie basin as herein defined embraces the eastern slopes of the Rocky mountains, the Mackenzie mountains, and Richardson mountains.

The eastern boundary of this province is a fairly definite line at which the foothills of the mountains die out in the Great Central plain. Starting in the south from a point near the intersection of latitude 53 degrees and longitude 116° 30', the line runs northwestward, crossing the Peace river near Hudson Hope and striking the Liard river near longitude 125 degrees. Here, the continuity of the Rocky mountains is interrupted and they appear to die away north of the river. Under the name Mackenzie mountains, however, the Cordillera springs up again north of the river, but its eastern front is stepped far to the eastward and abuts against the Liard river at Fort Liard. From this point the eastern boundary of the Cordilleran province runs northward, touching the Mackenzie river at the mouth of the Nahanni river and continuing thence along the western side of the Mackenzie to latitude 65° 30', where it turns in a broad curve and swings westward round the headwaters of Peel river. The Mackenzie mountains die out about the head of Peel river in much the same way as the Rockies north of the Liard river, but another lower range, known as the



Richardson mountains, springs up north of Peel river and extends down to the Arctic coast, its eastern front following closely the valley of Peel river and rising as an abrupt fault scarp out of the delta of the Mackenzie.

This physiographic province of the Mackenzie basin comprises three main mountain groups, namely, the Rocky mountains, Mackenzie mountains, and the Richardson mountains.

*Rocky Mountains.* The Rocky mountains occupy the southwestern portion of the basin and extend as far north as the valley of the Liard river, where they either die out or lose their lofty mountainous character in a region of foothills. To the south they extend far beyond the limits of the Mackenzie basin into southern Alberta and Montana.

In the Mackenzie basin, as elsewhere, the Rocky mountains are made up of a series of parallel ranges striking northwesterly and coinciding in trend with the direction of the main mountain axis. Between the ranges are deep longitudinal valleys occupied by the smaller streams, and crossing them at right angles are transverse gaps through which the major streams break eastward to the Great Central plain. The transverse valleys are usually short in comparison with the longitudinal valleys and only in a few instances do such transverse breaks preserve their character so definitely through the whole breadth of the mountains as to form direct passes. The most notable instance of this is the Peace river, which cuts a deep, wide valley directly across the strike of the Rocky mountains and draws much of its water from the country to the west of them.

Some of the loftiest summits of the whole Rocky Mountain system in Canada are situated at the extreme southern portion of the Mackenzie basin at the headwaters of the Athabaska river, where streams which flow eastward to the Atlantic, northward to the Arctic, and westward to the Pacific interlock and have their sources. Here, is a group of mountain peaks which exceed 10,000 feet in elevation and culminate in the highest point of all, mount Robson, 13,700 feet above the sea. Between the Athabaska and Peace rivers not much is known of the character of the Rocky mountains except that they are very rugged and high and there are no known passes as low as the Yellowhead pass, 3,720 feet in elevation. Approaching the Peace river, however, the mountains decrease in height and width and are traversed by some low passes. Pine River pass, which was estimated by Dawson<sup>1</sup> to have an elevation of 2,850 feet above the sea, traverses the ranges where the bordering summits do not rise more than 6,000 feet above the sea; and Peace river itself cuts a valley directly through the main ranges of the Rockies, where their highest points barely exceed 6,000 feet in elevation and the valley bottom is less than 2,000 feet.

Less is known of the Rocky mountains north of Peace river than of any other portion of the whole system. Points as high as 7,500 feet are mentioned by McConnell<sup>2</sup> as occupying the region about latitude 57 degrees, but where the ranges have next been observed, at the Liard river, they are seen to have decreased in height to such an extent that the highest points are not more than 4,000 feet above sea-level. Only one of the main ranges of the Rockies is said to cross the Liard river, near Rivière des Vents, and even this a few miles north of the river becomes greatly reduced in height. The foothills, however, which border the main

<sup>1</sup> Geol. Surv., Can., Rept. of Prog., 1879-80, p. 37 B.

<sup>2</sup> Geol. Surv., Can., vol. VII, 1894, p. 16 C.

range on the east, do cross the river with undiminished strength at Hell Gate and probably merge with some of the southern spurs of the Mackenzie mountains to the northward.

The whole of this portion of the Cordilleran province is drained by three principal streams, the Athabaska, Peace, and Liard rivers. These rivers have their sources either in the central ranges of the Rockies or in the western slopes, but flow eastward by transverse gaps from the central ranges through a broad belt of foothills to the Great Central plain.

*Mackenzie Mountains.* Mackenzie mountains represent the Cordillera from the Liard river to the Peel and are the northwestern continuation of the Rocky mountains. They resemble the Rocky mountains in general characteristics and are made up of a series of parallel ranges striking northwesterly in the southern part and almost east and west in the northern part. "They are the greatest mountain group in Canada and appear to consist of two ranges, an older western range, against the eastern edges of which a newer range has been piled."<sup>1</sup> The newer range as well as a part of the older range lies on the Mackenzie River slope of the divide.

Mackenzie mountains have been crossed in only two places, namely, on Gravel river by Keele and on Wind river by Camsell. Their eastern front, however, was ascended and examined by McConnell at Liard river and North Nahanni river. At the south they rise somewhat abruptly out of a low-lying level region to heights of about 6,000 feet, and on Gravel river the highest summits reach a maximum of 8,000 feet. To the north they decrease again in elevation and on Wind river rarely reach 7,000 feet. They appear to die away at the headwaters of Peel river in a comparatively low region broken only by a few fault scarps and anticlinal ridges.

A number of important streams have their sources in and traverse Mackenzie mountains. Those tributary to the Mackenzie are the Nahanni, Root, Gravel, Carcajou, Arctic Red, and Peel rivers. These all cut across the strike of the ranges and their valleys are often continuous across the divide with those draining to Yukon. All the streams have such high gradients that in no case do the natives make use of them when travelling from the valley of the Mackenzie into the mountains. They do, however, descend many of them in boats.

The divide at the head of Gravel river is given by Keele as 4,525 feet, but there are other passes leading to the headwaters of Macmillan and Stewart rivers which are said to be well below this level. The pass at the head of Wind river is estimated by Camsell at 3,400 feet. The vertical relief along the explored routes through these mountains ranges from 3,000 to 4,500 feet.

*Richardson Mountains.* North of Peel river, or from latitude 66 degrees, the Cordillera is represented by the Richardson mountains, a range which extends northward along the west side of Peel river to the delta of the Mackenzie where it swings westward as a coastal range bordering the Arctic coast.

These mountains are considerably lower in general elevation and have neither the length nor the breadth of Mackenzie mountains. They strike north and south and present other features which differ greatly from the other mountains of the Cordillera. McConnell<sup>2</sup> describes them as consisting essentially of two ranges

<sup>1</sup>Keele, J., "A reconnaissance across the Mackenzie mountains," Geol. Surv., Can., 1910, No. 1097.

<sup>2</sup>Geol. Surv., Can., vol. IV, 1888-89, p. 119 D.

separated by a wide longitudinal valley and flanked on either side by high plateaus. The eastern range has a width opposite Fort McPherson of 7 miles and its higher peaks are estimated to reach an altitude of 4,000 feet above the sea. They rise more or less easily from the valley of Peel river, but present a steep face about 3,000 feet in height to the delta of the Mackenzie. The western range is much narrower and at Rat river does not exceed 4 miles in width, but spreads out to the south. The valley of Peel river, which skirts the eastern base, is fully 1,200 feet lower than Bell river on the western side and the drainage of the mountains is mostly towards Peel river.

The summits of this northern division are usually rounded in outline and show few sharp peaks, a feature which may be due either to mature erosion or to lack of close folding of the strata. The pass at the head of Rat river has an elevation of about 1,100 feet above the sea, and this is about the upper limit of tree growth in this part of the range.

### *The Great Central Plain*

This physiographic province occupies the central portion of the Mackenzie basin and includes all the region between the Laurentian plateau on the east and the Cordilleran region on the west. It extends throughout the whole length of the Mackenzie basin and has a length of about 1,300 miles. Its width ranges from a maximum of 420 miles along a line drawn across it through Fort Vermilion, to about 200 miles in latitude 63 degrees.

The Great Central plain of the Mackenzie basin is not as might be supposed a vast area of level country tilted with a uniform grade to the north, but its surface features are somewhat diversified. It has a general northward slope and along the valley of the main streams flowing through the plain the slope is generally uniform; but the Great Central plain is really made up of a north-easterly sloping plateau at the south, bounded by an escarpment or series of escarpments facing on to a lowland which extends northward to the Arctic.

South of the Mackenzie basin in southern Alberta and Saskatchewan, this plateau is referred to by Dowling<sup>1</sup> as the Cretaceous plateau since its limits are coterminous with the boundary of the Cretaceous rock and its escarpment is built of Cretaceous strata. In the Mackenzie basin, however, the name is not appropriate since the escarpment of the plateau consists more often of Devonian rocks. It is proposed, therefore, to call this plateau of the Great Central plain the Alberta plateau, as its northern limits almost coincide with the boundary of that province. A smaller plateau occupies the upper part of the basin of Peel river and this has been called the Peel plateau<sup>2</sup>. The lowland portion of the Great Central plain is known as the Mackenzie lowland.<sup>3</sup>

Both the plateaus and the lowland have their surfaces broken by a number of hills or higher plateaus which rise from 1,000 to 3,000 feet above the level of the surrounding country.

*The Alberta Plateau.* This portion of the Great Central plain covers virtually the whole region south and southwest of Great Slave lake. It corresponds to the second and third prairie steppes in the Great Plains region south

<sup>1</sup> Physical geography of Canada; Thirteenth report of the Geographical Board of Canada, 1914. See map.

<sup>2</sup> Camsell, C., Geol. Surv., Can., vol XVI, pt. CC, p. 23.

<sup>3</sup> Dowling, D. B., op. cit.

of the height of land<sup>1</sup> and though such a two-fold division might be made in the Mackenzie basin also, we have not as yet sufficient information of the topography to enable us to make it. The boundary of the plateau is marked by a series of north facing escarpments which extend from near Fort Smith on Slave river northwesterly along the south side of Great Slave lake and thence at an equal distance along Mackenzie river to the Liard in longitude 122 degrees. Here the escarpment is lost, although from McConnell's<sup>2</sup> observations it may swing southwest along the valley of Liard river. South of Fort Smith the plateau seems to merge into the Laurentian plateau.

Unlike the escarpment in Manitoba it is here not coincident with the eastern boundary of the Cretaceous rocks, but is built mainly out of Palæozoic limestones which overlie softer shales and so, in the course of erosion, give steepness to the slope. The smaller streams that break through from the plateau to the lowland all do so with high falls or strong rapids. Falls exist along this line on Little Buffalo river, Hay river, and Beaver river, and strong rapids occur at corresponding points on Buffalo river, Trout river, and the Liard. The larger streams, namely the Peace and the Athabaska, are, however, graded throughout and cut picturesque, terraced valleys in the plateau, that become gradually deeper and deeper to the southwest as the mountains are approached. For example, the valley of Peace river at Fort Vermilion is only about 100 feet deep, whereas at the mouth of Smoky river 300 miles farther upstream it is 700 feet deep and has a width of about 2 miles.

The top of the escarpment stands about 400 feet above the level of the adjacent lowland and the surface then rises gradually southwest and west to the foothills of the Cordillera. The slope, however, is so gradual that the smaller streams which have not the power to cut graded valleys from the plateau to the lowland, are comparatively sluggish in the plateau and are rapid and broken only where they descend through the escarpment. The surface, therefore, is monotonous and outcrops of the solid rocks are rare, and because the drainage is immature, muskegs are abundant and lakes fairly numerous. There are also many areas of open prairie land, especially in the basin of Peace river where settlement by agricultural communities is rapidly taking place.

The surface of the plateau is relieved by several higher plateaus or ridges which rise 1,000 or 2,000 feet above it. Of these, Caribou mountain, or as it should more correctly be called, Caribou plateau, is situated between Peace river and Great Slave lake east of Hay river and covers an area of about 8,000 square miles. From the incomplete knowledge we have of its general character it appears to be a remnant of an older plateau, which is separated from the Laurentian plateau by the wide plains of Slave river above which it rises to a height of about 2,500 feet. The slopes on the north and east sides are said to be rather steep. On the south they are more gentle, and on the west they are still more so. The plateau is said to contain a number of lakes and is forested by a stunted growth of spruce similar to that which grows on the borders of the Barren lands or near the timber-line in the mountains.

Buffalo Head hills, which lie south of Peace river, rise abruptly from the plateau about 50 miles west of Wabiskaw river to an elevation of about 2,500 feet above the sea and, running in a south-southwesterly direction, die away

<sup>1</sup>Dowling, D. B., Physical geography of Canada; Thirteenth report of the Geographic Board of Canada, 1914.

<sup>2</sup>Geol. Surv., Can., vol. IV, 1888-89, pt. D.

opposite the mouth of Battle river. They are said by McConnell<sup>1</sup> to be about 50 miles long and from 25 to 35 miles wide.

Birch mountain extends for nearly 90 miles along the western side of Athabaska river below McMurray and has a width of about 35 miles. Its slopes on all sides rise easily to a maximum height of 2,300 feet above the sea, or about 1,000 feet above the surrounding country. The surface of the mountain is rolling and drift covered and the depressions are frequently occupied by lakes. It is all heavily wooded.<sup>2</sup>

Martin mountain, situated east of Lesser Slave lake and rising 1,000 feet above it, runs east and west for about 60 miles and is similar in general character to Birch mountain.<sup>3</sup>

Clear hills, north of Dunvegan, have a maximum height of 3,500 feet above the sea or 1,500 feet above the general level of the plateau, but their extent and general character are not clearly known.

Several other smaller ridges and plateaus, such as Pelican mountain and Thickwood hills, are described in McConnell's report of the country south of Peace river<sup>4</sup> and there are no doubt many others which rise out of the plateau in the large tract of unexplored territory north and west of Hay river. All are erosion plateaus.

*Peel Plateau.* A plateau similar in character to that just described occupies the upper part of the basin of Peel river.<sup>5</sup> This plateau extends south and west from the mouth of Satah river on either side of the valley of Peel river up to the base of the Richardson mountains, but its extent eastward is unknown. It is possible, however, that it forms a flanking platform to the Cordillera and extends east and south towards the valley of the Mackenzie.

On the north side, the Peel plateau forms an abrupt escarpment overlooking the lowland and rises gradually southward until it stands about 1,500 feet above the sea. Its surface is apparently flat but is in reality made up of several long undulations having a north and south trend. Peel river cuts a valley in the plateau, ranging from 700 to 1,000 feet deep.

Towards the upper part of Peel river the plateau forms a great bay in the mountains and in this bay its level is broken by several short ranges of mountains which are in reality outliers from the main Cordillera. These ranges are short, isolated hills seldom rising more than 2,000 feet above the plateau and frequently less than 1,000 feet. These hills enclose a shallow depression on the surface of the plateau which embraces the lower parts of the Wind and Bonnet Plume rivers. This depression was formerly a lake basin which, however, has since been drained, though the sediments that were deposited in it still remain to prove the former existence of the lake.

The eastern limit of the broken hilly country of the plateau lies at Snake river, beyond which the plateau stretches eastward with an unbroken sky-line for an unknown distance. It is everywhere covered with moss and wooded with small spruce and tamarack, and holds many small muskeg lakes on its surface.

The plateau gradually narrows in width northward as the Mackenzie approaches the mountains until it eventually merges into the mountains and disappears near Rat river at the head of the delta.

<sup>1</sup> Report on the district of Athabaska, Geol. Surv., Can., vol. V, pt. I, p. 15 D.

<sup>2</sup> McConnell, R. G., *op. cit.*, p. 44 D.

<sup>3</sup> McConnell, R. G., *op. cit.*, p. 7 D.

<sup>4</sup> Geol. Surv., Can., vol. V, pt. I, 1890-91, pt. D.

<sup>5</sup> Camsell, C., Geol. Surv., Can., "Peel river and tributaries," 1906.

*Mackenzie Lowland.* The lowland portion of the Great Central plain of the Mackenzie basin commences in the lower part of Peace river and the extreme western end of lake Athabaska, whence it extends as a narrow band down the valley of Slave river to Great Slave lake. Its eastern boundary here as well as north of Great Slave lake is the border of the Laurentian plateau. It embraces the basin of the western end of Great Slave lake and continues thence down the valley of Mackenzie river to the Arctic coast, its eastern boundary being as far as known the Laurentian plateau, and its western Mackenzie mountains and the escarpment of the Peel plateau. A re-entrant of the lowland extends up the valley of Liard river as far at least as Fort Liard.

The limits of the lowland on the south are well defined and marked by a distinct topographic break at the escarpment of the Alberta plateau. North of Liard river the lowland reaches on the west to the base of Mackenzie mountains which are here not bordered by an elevated plateau belt. North of Nahanni river, however, the long narrow ridge of Franklin mountains divides the lowland into two parts by separating a strip 20 to 80 miles in width, through which the Mackenzie flows, from the main portion of the lowland lying in the drainage basin of Great Bear lake. Franklin mountains are believed to die out about latitude 66 degrees, and from this line northward the lowland is bounded on the west by the escarpment of the Peel plateau and farther north by Richardson mountains, whereas on the east its limits are unknown though it probably extends across the height of land into the watershed of Anderson river.

So far as it is possible to determine from our imperfect knowledge of the eastern portions of the lowland there is no well-defined and continuous break between the lowland and the Laurentian plateau such as occurs in the west, but the plateau, as a rule, dips gently westward under the overlapping edges of the flat-lying sedimentary strata which constitute the bedrock of the lowland.

The elevation of the lowland at the west end of Athabaska lake is about 700 feet above the sea and the slope of the surface from that point to the Arctic averages about 8 inches to the mile and is so gradual that from Fort Smith to the Arctic ocean, a distance of over 1,300 miles by the river, steamers with a draft of 5 feet are able to run without encountering any obstructions from rapids or falls.

The surface as a rule does not stand much above the main water courses or the great lakes and the banks of these are rarely more than 200 feet in height.

The great bodies of water, Great Slave and Great Bear lakes, occupy areas of depression in the surface of the lowland, and another long narrow depression, not, however, now filled with water, lies along the base of Mackenzie mountains from Fort Liard to the mouth of North Nahanni river.<sup>1</sup>

Rising above the general level of the lowland are a number of hills and mountain ranges varying in height from a few hundreds of feet to about 4,000 feet. Such ranges are: Horn mountain, northwest of Providence; Franklin mountains, between the Mackenzie and Great Bear lake; Grizzly Bear mountain and Scented Grass hills on the shores of Great Bear lake; Reindeer hills, east of the delta; and a number of other short ranges or isolated hills.

These ranges are the only features that relieve the monotony of an otherwise flat plain which holds on its forested surface innumerable lakes and muskegs, and through which the smaller streams meander in shallow valleys. Only in the

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<sup>1</sup>McConnell, R. G., Geol. Surv., Can., vol. IV, 1888-89, pp. 57 D and 89 D.

south along the valleys of Peace, Slave, and Liard rivers and the Mackenzie above the mouth of the Liard, is the land sufficiently well drained to be suitable for agricultural purposes. North of this, except on the islands and banks of streams, the surface is generally covered with a thick moss which prevents the ground beneath from ever thawing out beyond a depth varying from 6 inches to 6 feet. A thick forest of small spruce, tamarack, and willows extends over the whole of the lowland to the newly formed land at the seaward edge of the delta.

The southernmost of the ranges which rise out of the Mackenzie lowland is Horn mountain situated north of the Mackenzie between Providence and Simpson. The mountain is visible from the river all the way between these two points, at a distance of about 20 miles from the river. It has the character of a simple escarpment with a steep face to the south and a very gentle slope to the north.<sup>1</sup> Its summit stands about 1,000 feet above the sea.

The Franklin range, which extends along the east side of Mackenzie river from old Fort Wrigley northward beyond Great Bear river, is considered by McConnell to be an outlier from Mackenzie mountains which does not actually cross the river but marks an entirely new line of disturbance. The Rock-by-the-river-side, however, near the present site of Wrigley, forms part of a small range which strikes in a direction diagonal to the main ranges and connects the Franklin range with the main portion of Mackenzie mountains.

The Franklin range at its south end rises easily out of the lowland as a narrow wooded ridge. It continues northward in a series of round-topped eminences flanked in places by plateaus, and, gradually increasing in height, culminates in the highest of them all, mount Clark. Mount Clark is a flat-topped mountain situated 8 or 10 miles back from Mackenzie river north of Blackwater river and is estimated by McConnell to be between 3,000 and 4,000 feet in height. From the northern shoulder of this mountain a line of lower elevations extends northward to Great Bear river and crossing it continues in a northerly direction for an unknown distance. A wide gap is cut in the range by Bear river at a point where the highest mountain, mount Charles, is 1,500 feet in height. Several other streams, the most important of which is Blackwater river, have their sources on the eastern side of the range and flow westward through gaps in it to join the master stream of the Mackenzie.

Another of the higher tracts that break the monotonous level of the lowland is Grizzly Bear mountain which occupies the peninsula between Keith and McVicar bays. The mountain is estimated by Sir John Richardson<sup>2</sup> to be 900 feet in height, but since many of Richardson's estimates have been proved to be too low it is probably somewhat higher. Preble<sup>3</sup> considers it to be higher than mount Charles which Bell<sup>4</sup> gives as 1,500 feet. It is a massive, round-topped ridge quite devoid of trees for several hundred feet of its upper portion.

Scented Grass hills, on the north shore of Great Bear lake, form the peninsula between Smith bay and the northern indentation of Keith bay known as Richardson bay. They are a round-topped ridge similar to Grizzly Bear mountain in general character and height and terminating to the east in a prominent point known as Gros Cap.

Between the Franklin range and Mackenzie mountains, Mackenzie river flows through a forested plain 20 to 80 miles in width, which, however, is broken

<sup>1</sup>McConnell, R. G., Geol. Surv., Can., vol. IV, 1888-89, p. 84 D.

<sup>2</sup>Narrative, second expedition to polar sea, Appendix, p. ii, 1828.

<sup>3</sup>North American fauna No. 27, U.S. Dept. of Agric., 1903, p. 43.

<sup>4</sup>Geol. Surv., Can., vol. XII, 1899, p. 8 C.

by several hills and plateaus of lower elevation than the bounding ranges. Several of these hills rise abruptly from the river to heights of 1,000 or 1,500 feet and because of their accessibility have been ascended and described by various travellers. The Rock-by-the-river-side, also known as Roche Trempe-l'eau, 1,500 feet in height, has already been referred to as one of the points of a range connecting Mackenzie mountains with the Franklin range.

The isolated hill known as Bear Rock is another hill standing in the northern angle between Great Bear river and the Mackenzie. It is a flat-topped mountain rising 1,400 feet above the river and presenting its steepest face towards it. It runs in a northerly direction for about 4 miles and is the southern-most of a line of similar hills which extend northward along the valley of Mackenzie river. Another conspicuous elevation is Roche Carcajou situated about 100 miles below Bear Rock on the right bank of the river. It is about 1,000 feet in height and presents sheer cliffs rising for several hundred feet directly out of the water of the river. A weathered knob, whose summit from some points of view resembles the figure of a wolverine, gives its name to the mountain.

About 20 miles below Roche Carcajou the Mackenzie flows between two peaks of a low range, which are known as the East- and West-mountains-of-the-rapid. From this point, northward, the lowland through which the river flows is unbroken by any outstanding hills or ranges as far as the Lower Ramparts where the river cuts through the southern end of a low ridge. This ridge strikes north and rising in elevation in that direction becomes known as Reindeer mountains (Plate II B), or as referred to by Preble, Caribou mountains<sup>1</sup>. These mountains are described by Richardson<sup>2</sup> as following a course parallel to the east bank of the river. They rise to a height of 700 or 800 feet above the river, are uniform in outline, and have rounded summits. They diminish in height beyond latitude 68 degrees and gradually die out in the low land of the delta. To the northeast of their northern extremity a low escarpment rises abruptly from the east shore of Gull lake and faces west over the Mackenzie delta in the same way that the higher fault scarp of the Richardson mountains overlooks the delta from the west.

So much of the whole Mackenzie basin lying back from the main water courses yet remains to be explored that no doubt other topographic features than those just described will be discovered, which will tend to increase the diversity of a region at present considered to be of a generally uniform character.

## RIVERS

### *Athabaska River*

Athabaska river (Plate III A) drains an area of 53,900 square miles and has a length from headwaters to lake Athabaska of 765 miles. It rises on the eastern slope of the Rocky mountains near latitude 52° 30', its headwaters interlocking with those of Columbia and Fraser rivers about a group of high peaks of which mount Robson is the highest. The passes through the mountains at the headwaters of the river are all high with the exception of Athabaska pass, 6,025 feet, and Yellowhead pass, through which the Grand Trunk Pacific railway runs at an elevation of 3,720 feet.

<sup>1</sup> North American Fauna No. 27. U.S. Dept. of Agric., 1908, p. 34.

<sup>2</sup> Narrative Second Expedition to polar sea, Appendix, p. XXXVIII.



From its sources until it leaves Brûlé lake the river lies in the mountains where its grade is too steep for navigation. Beyond this point it pursues a northeasterly course, cutting a deep valley through the Alberta plateau and receiving in succession the waters of Baptiste river from the west, McLeod and Pembina rivers from the south, and Lesser Slave river from the northwest. The mouth of McLeod river, elevation 2,262 feet, is considered to be the upper limit of possible steamboat navigation, which then extends for a distance of 325 miles down to the head of Grand rapids. This portion of the river has an average fall of about 3 feet to the mile and is broken by a number of minor rapids, especially above the town of Athabaska, but none of them is sufficiently rough to obstruct the passage of steamboats during medium and high stages of water. Rapids also occur on Lesser Slave river, but in these the channel has been improved and deepened so as to allow steamboats to ascend the river to Lesser Slave lake. Lesser Slave river is one of the largest tributaries of Athabaska river and at ordinary high-water stage has a discharge of about 2,300 cubic feet per second.

From Athabaska the river has a more northerly trend and although the stream runs with a strong current it is not broken by any rapids as far as Pelican rapids, a distance of 120 miles. Pelican rapids, however, present no difficulties to navigation except in low water when the channel is obstructed by some boulders. Broken water also occurs at two other points below Pelican rapids, but boats which are able to navigate Pelican rapids would have no difficulty in descending the additional 45 miles to Grand rapids which is the lower limit of steamboat navigation on this portion of the river. The river in this portion is from 250 to 400 yards wide and its valley varies from 300 to 400 feet in depth.

At Grand rapids the character of the river changes, its grade becomes greatly increased, and for the next 85 miles or as far as the mouth of Clearwater river it is broken by swift and dangerous rapids every few miles. The average grade of this portion is nearly 5 feet to the mile and the valley is 500 to 600 feet deep and frequently gorge-like. This portion is navigable only for scows or canoes and that with difficulty.

At Grand rapids (Plate III B) the river falls 50 or 60 feet in about half a mile and the main channel is not navigable by craft of any kind. A small island about a quarter of a mile long lies opposite the worst part of the rapids and over this goods are carried, and the scows are run down empty to the east of the island through a channel that has been blasted out among the boulders.

Rough water which requires some care in navigation extends for 2 or 3 miles below Grand rapids, but beyond this the river runs smoothly for over 20 miles to what are known as Burnt rapids. Here the stream widens to 400 yards and becomes shallow and occupied by scattered boulders. The canoe and boat channel follows the left side of the river and by keeping not more than 20 or 30 yards from the shore there should be no danger to experienced boatmen in the descent.

About 16 miles of smooth water follows Burnt rapids, below which the river falls in quick succession over Boiler, Drowned, Middle, and Long rapids, all of which occur within a stretch of 7 miles. They are all similar in character to Burnt rapids and owe their existence to a steepening of grade and an accumulation of boulders in the channel. In Boiler rapid the boat and canoe channels are on the left side and are so crooked that much care must be exercised to navigate them with safety. In Drowned rapid the channel is also on the left side and is somewhat rough. About a mile below is Middle rapid which presents no great

difficulties except those caused by shallow water and a few boulders. In this and Long rapid, which follows and is easily navigable, the channels are on the right side of the river.

About 5 miles below Long rapid the river makes a sharp bend, at the end of which is Crooked rapid, where ledges of limestone project into the stream from the right side. The channel is on the right side where the only danger is from the large swells. Immediately below is Stony rapid where the stream flows over a solid rock bed and is very shallow. The canoe channel follows the right shore.

At the foot of Stony rapid a crossing should be made to the left side in order to descend Little and Big Cascades which follow. These are caused by ledges of limestone extending across the river, but they are broken down in places enabling boats to get through. At Big Cascade a direct fall of about 4 feet occurs on the right side, but on the other side this is resolved into a series of smaller drops and rapids that presents no serious difficulty in ordinary high water.

At Mountain rapid, 9 miles below, the river is again obstructed by ledges of limestone, but it is possible to avoid the rough water by descending the upper portion on the left side, crossing in the middle over a piece of comparatively smooth water, and descending the remainder of the rapid on the right side.

Mountain rapid is the last dangerous rapid on the river, though a riffle occurs 2 miles above McMurray at what is known as Moberly rapid.

Clearwater river, which joins the Athabaska from the east at McMurray, is one of the largest tributaries of the Athabaska, but is navigable without interruption for only about 40 miles when strong rapids occur.

Below the mouth of Clearwater river, which has an elevation of 815 feet above the sea, the character of the Athabaska changes. Rapids disappear, and the Athabaska, enlarging to one-third of a mile or more in width, flows smoothly at an average rate of 3 miles an hour with a grade as far as Athabaska lake of about 8 inches to the mile. Islands become numerous, the valley increases in width, and the banks gradually decrease from an elevation of about 400 feet at McMurray to the water level at Athabaska lake. The stream enters its delta about 35 miles from the lake and divides farther down into several branches whose channels are constantly changing as a result of the sediment and other material carried down by the stream. The distance from McMurray to Athabaska lake is about 175 miles and the only obstructions to steamboat navigation in this distance are the sand-bars and the shifting of the channel at the outlet.

#### *Tributaries of Athabaska Lake*

With the exception of Peace and Athabaska rivers there are no streams flowing into Athabaska lake that are navigable for more than a few miles without interruption. On the south shore of the lake the most important streams are Old Fort, William or Gaudet, and Grand Rapids rivers. These rivers drain a large area of country south of the lake, but they are all shallow and so interrupted by rapids that they are navigable by canoe with difficulty, and that only in the high-water stages.

On the north shore of the lake the streams are all short and none of them is navigable even by canoe, the reason being that the height of land between Athabaska lake and the streams flowing northward to Great Slave lake lies only a few miles north of the shore of the lake.

Stone or Black river which flows into the extreme eastern end of the lake is a large stream rising in Wollaston lake, at a height of 1,300 feet above the sea.

Its course lies entirely within the Laurentian Plateau region and it has in consequence the characteristics of the streams of that region, that is to say numerous rapids or falls and lakes. On leaving Wollaston lake it flows northwestward through several small lakes almost as far as Waterfound river in a country underlain by granite and gneiss. Here the stream enters an area of sandstone in which it cuts a shallow valley and is obstructed by numerous rapids and falls many of which have to be portaged. It enters Black lake at the east end by two channels and where it leaves it on the west side is 300 feet wide. Between Black lake and lake Athabaska the river falls 300 feet, mainly in three strong rapids at each of which a portage has to be made.

### *Peace River*

Peace river is formed by the junction of Finlay and Parsnip rivers and is the largest and longest of the tributaries of Mackenzie river. It rises on the western side of the Rocky mountains and, flowing eastwards, cuts through the axis of that range and drains a large area of country on its eastern slopes. The total area of its drainage basin is 117,100 square miles and its length from the sources of the Finlay to its junction with the Slave is 1,065 miles.<sup>1</sup>

The Finlay rises near the headwaters of Skeena river and flows southeasterly down the great valley known as the Rocky Mountain trench, and the Parsnip, rising near the sources of some of the branches of the Fraser, flows in a northwesterly direction in the same great valley. On joining to form the Peace the latter turns at right angles and flows easterly in a deep valley which cuts directly across the main ranges of the Rockies.

From the confluence of Finlay and Parsnip rivers, which has an elevation of 2,000 feet above the sea, to Hudson Hope, a distance of about 120 miles, Peace river traverses the main ranges of the Rockies and their bordering foothills. Its valley averages about a mile in width and ranges from 2,000 to 4,500 feet in depth. The stream is from 300 to 500 yards in width and its current seldom exceeds 5 miles an hour. One rapid occurs just below the mouth of Finlay river and another, known as Parle-pas rapid, about 35 miles below.

For the last 25 miles of its course through the mountains and before reaching Hudson Hope the Peace flows through the canyon of the Mountain of Rocks, to avoid which a portage 12 miles in length has to be made on the north bank. The stream here contracts in places to about 150 feet in width and has a total drop of about 275 feet.

Hudson Hope is the head of the steamboat navigation for a stretch of about 550 miles of river, which extends from this point down to Vermilion chutes near the mouth of Mikkwa river. In this distance the stream has an average fall of about one foot to the mile and the only obstructions to navigation are shallow bars which in low water make parts of the river unnavigable.

The river varies in width from a quarter to a half a mile and is frequently divided by islands. The valley is cut to a depth of about 800 feet in the plateau but this depth gradually decreases until at the Chutes it is not more than 100 feet. Its course as far as Peace River Crossing is westward and in this portion it receives a number of tributaries, namely the North and South Pine rivers and Smoky river. Smoky river is the most important tributary of the Peace, not only on account of its size and length, but because it drains a large area of excellent agricultural territory, partly prairie and partly forested, which is rapidly being settled by ranchers and farmers.

<sup>1</sup> White, James, Atlas of Canada, Dept. of Interior, 1906.

From Peace River Crossing to Fort Vermilion the course of the river is northward, the valley is deep and picturesque, and the current has a uniform rate of 3 to 4 miles per hour. In the lower part of this stretch the valley widens, islands become more numerous, and the shores and bars gradually change from gravel to sand or mud.

Wabiskaw river enters from the south about 20 miles below Fort Vermilion and is the most important tributary below Smoky river. McConnell<sup>1</sup> considers that this stream might possibly be navigated as far as Grand rapids, 9 miles above Panny creek, by powerful steamers with the aid of a line, but with the exception of a few miles of still water above its mouth it can hardly be considered a navigable stream.

At Vermilion chutes a rapid and fall with a total drop of 25 feet obstruct the course of navigation and make a portage of 5 miles on the south bank necessary. The chutes are caused by a ledge of limestone projecting across the river and though the rapid at the head is navigable, with difficulty, by a canoe, the falls below have a direct drop of 15 feet and cannot be run by any sort of boat.

Mikkwa river, which joins the Peace immediately below the chutes, is about 240 miles in length, but is a swift and shallow stream broken by numerous rapids and navigable only by canoes during high water.

Below Vermilion chutes, Peace river increases in width and its valley almost disappears. In the 220 miles to Slave river it falls about 110 feet, or 6 inches to the mile. Its current is consequently more gentle, and only at one point, a few miles below the mouth of Jackfish river, does it break into a rapid, which, however, is not a serious hindrance to navigation by shallow-draft steamboats. At this point and for 20 miles down, the stream is confined by cliffs of gypsum from 20 to 80 feet in height, but at no other points are the banks composed of anything except sand or clay.

Jackfish river is a stream 50 yards in width at its mouth, entering Peace river from the north, and is the most important tributary below Mikkwa river. It rises on the eastern slope of Caribou plateau and flows in a meandering course through a level country. It is navigable by canoes for about 200 miles with two or three interruptions.<sup>2</sup>

In ordinary stages of water Peace river discharges all its water directly into Slave river, but in flood time much of it flows by way of Quatre Fourches river into the western end of lake Athabaska and thence by Rocher river into the Slave. During these periods of flood the Peace becomes heavily laden with sediment. It has formed a great delta plain which has been gradually built out into the western end of Athabaska lake and has thus cut off a large body of water, lake Claire, from the main portion of the lake.

Stream measurements conducted at Fort Vermilion by officers of the Department of the Interior have shown that at that point Peace river has an extreme low-water discharge in the month of February of about 7,500 cubic feet per second. In flood time in July the volume of water increases to about 300,000 cubic feet per second.

### *Slave River*

Slave river connects Peace river and Athabaska lake with Great Slave lake. A short portion of it, about 30 miles long, connecting Athabaska lake with Peace river, is known locally as Rocher river, but the name seems unnecessary. The total length of the river is about 300 miles.

<sup>1</sup> Geol. Surv., Can., vol. V, 1890-91, p. 13 D.

<sup>2</sup> Camsell, C., Geol. Surv., Can., vol. XV, 1902-03, p. 164 A et seq.

Rocher river, the outlet of Athabaska lake, has an average width of about 150 yards and an easy current. A small rapid occurs on it about 10 miles above the mouth of the Peace, but presents no difficulty to steamboats or canoes, except in extreme low water, when a portage frequently has to be made even with canoes.

Slave river after receiving the Peace becomes a broad and deep stream from one-third to two-thirds mile in width and has a current which runs at a uniform rate of about 3 miles an hour. To the head of the rapids at Fitzgerald or Smith Landing, a distance of 71 miles, the river flows between low wooded banks where solid rock outcrops only occasionally. No rapids of consequence occur in this stretch and no streams of importance enter.

From Fitzgerald to Fort Smith, 16 miles, the course of the river is interrupted by a series of dangerous rapids to avoid which a wagon road has been built on the west bank for the purpose of transporting supplies for the Mackenzie River district. The rapids have a total fall of 125 feet, instrumentally measured, and are caused by a gneissic spur from the Laurentian Plateau region which crosses to the west of the river at this point. In these rapids the river spreads out to  $1\frac{1}{2}$  or 2 miles in width and contains many rocky islands. The descent of the rapids by boat is accomplished on the east side and five or six portages have to be made, but the course is so intricate and dangerous that it should not be attempted without the services of a good guide.

The rapids at Fort Smith constitute the head of navigation for steamers running in northern Mackenzie waters, which are unobstructed from this point northward into the Arctic ocean. If locks could be constructed here, permitting steamers to surmount the rapids, boats leaving the end of the railway at McMurray could descend the river to the Arctic ocean, with a run of 1,630 miles.

Slave river below the rapids is a monotonous stream winding through a level alluvial country, between banks of clay and sand which at Fort Smith are about 100 feet high but become gradually lower northward. The stream has an average width of about half a mile and a grade of about 6 inches to the mile. The only important stream entering it is Salt river, a stream about 30 yards wide at the mouth and draining a considerable tract of country to the west, partly forest and partly prairie. In places, Slave river meanders widely, forming bends which are several miles around but only a few hundred yards across. For example, at Grand Detour the river flows 15 miles around a big point, the base of which is about 1,000 yards across, whereas at point Ennuyeux the distance around is 10 miles and the portage across is only half a mile.

The banks below Fort Smith are composed entirely of sand or clay and only at two points do the solid rocks outcrop, namely, at Bell Rock, a massive cliff of limestone 7 miles below Fort Smith, and on the point below point Ennuyeux where beds of gypsum are exposed just at the water's edge.

Slave river enters Great Slave lake by many channels through a delta of low alluvial islands, the delta having a spread across the outward side of about 20 miles. An enormous amount of sediment carried by the river is deposited in the delta which is gradually being built out into the lake threatening to cut off the eastern and northern arms from the western arm.

#### *Tributaries of Great Slave Lake*

The principal streams flowing into the western arm of Great Slave lake are Little Buffalo, Buffalo, and Hay rivers. These all enter from the south, and on the north no streams of importance are known.

*Little Buffalo River.*<sup>1</sup> This is a stream about 50 yards wide at its mouth, entering Great Slave lake. The area of its basin is 25,700 square miles. Above 60 miles southwest of Fort Smith on the eastern slope of Caribou plateau and flows thence northeasterly in a shallow valley through a level forested country. Directly west of Fort Smith it turns northward and precipitates itself in a series of falls over a limestone escarpment which forms the boundary of the Alberta plateau, and for 7 miles below flows through a rocky gorge 100 feet in depth.<sup>2</sup> Below this it parallels Slave river and at Grand Detour approaches within a few miles of it. Here travellers by canoe frequently make a portage from Slave river and use Little Buffalo river as an alternative and shorter route to Great Slave lake. The stream can be navigated by canoe virtually to its head, but only in high water and by making a portage at the falls.

*Buffalo River.* Buffalo river enters Great Slave lake about 60 miles west of Resolution, and is stated by Ogilvie<sup>3</sup> to be about 100 yards wide at its mouth. It is said to rise in the Caribou plateau, at the northern base of which it flows through a large lake, described and surveyed by A. E. Cameron<sup>4</sup> of the Geological Survey in 1917.

From Buffalo lake to Great Slave lake is a distance of 75 miles, in which Buffalo river flows through a level country in a shallow valley 50 to 100 feet in depth. Rapids occur at several points, the most important of which are about 20 miles above Great Slave lake where the river descends a steep chute in a narrow limestone gorge, making a portage necessary when travelling by canoe.

*Hay River.* This river enters Great Slave lake 17 miles west of Buffalo river, and is the largest stream flowing into the west end of Great Slave lake. McConnell<sup>5</sup> describes it as rising near the headwaters of Fort Nelson river, the east branch of the Liard, and flowing in a northeasterly direction for 300 miles before entering Great Slave lake about 12 miles southwest of Resolution. It rises about Alexandra falls it is easily navigable by canoe and flows with a fairly uniform grade through a comparatively level, wooded country. Hay lake, an expansion through which the river flows, is said to be a large lake, though shallow, with low marshy shores. The river was surveyed by A. E. Cameron<sup>6</sup> in 1917, from the crossing of the 6th meridian down to Great Slave lake.

At Alexandra falls (Plate I) the river, which is 130 yards wide, precipitates itself over a limestone escarpment in two falls, the upper one of which is a sheer drop of 105 feet, whereas the lower one (Plate IV A), about a mile and a half below, has a drop of 46 feet in a series of steps. Below are 3 miles of rapids and a gorge 170 feet deep which continues for 5 miles below the lower fall. A portage of about 2 miles has to be made to avoid both falls.

The falls are about 20 miles in a direct line from the mouth of the river, but because of its windings the distance by the river is about 43 miles. The stream is swift but deep enough in high water for shallow-draft steamers, and its valley is about a quarter of a mile wide. It forms a small delta at its mouth and enters Great Slave lake by two main channels.

<sup>1</sup> McConnell, R. G., Geol. Surv., Can., vol. IV, 1888-89, p. 68 D.

Ogilvie, W., Rept. of Dept. of the Interior, Can., 1889-90, pt. VIII, p. 76.

<sup>2</sup> Camsell, C., Geol. Surv., Can., vol. XV, 1902-03, p. 159 A.

<sup>3</sup> Rept. of Dept. of the Interior, Can., 1889-90, pt. VIII, p. 76.

<sup>4</sup> Geol. Surv., Can., Sum. Rept., 1917.

<sup>5</sup> Geol. Surv., Can., vol. IV, 1888-89, p. 69 D.

<sup>6</sup> Geol. Surv., Can., Sum. Rept., 1917.

The northern arm of the lake has only two streams of consequence flowing into it, namely, Yellowknife river on the east and Grandin river at the extreme north end.

*Grandin River.* At its mouth Grandin river is 50 yards wide and has a rather strong current. The first rapid is only a mile up and others at which portages have to be made follow in quick succession. The river has many branches, the main one being La Martre river which enters from the west and drains the large lake of the same name. Grandin river flows from the north through a rocky lake region and forms part of the regular Indian canoe route between Great Slave lake and Great Bear lake, a route followed and described by J. M. Bell<sup>1</sup> and E. A. Preble.<sup>2</sup>

*Yellowknife River.* This is a comparatively short stream, but is important as being the canoe route from Great Slave lake to the upper waters of Coppermine river. It lies entirely within the rocky Laurentian Plateau region and its course is consequently through a succession of lakes connected by rapids or falls at which portages are necessary. It was explored by Sir John Franklin in 1820, whose description of the river is still the best to be had.<sup>3</sup>

The eastern arm of Great Slave lake has several streams emptying into it many of which are unknown beyond their mouths. The important streams are Taltson river on the south, Lockhart river at the east end, and Hoarfrost river on the north side.

*Taltson river* drains the greater part of the region between lake Athabaska and Great Slave lake. It rises in the Barren lands near the headwaters of Thelon river and flows westward and then northward through a series of lakes and connecting rivers until it empties into Great Slave lake at the eastern edge of the delta of Slave river. It is not a navigable stream for anything but canoes and could be ascended by steamboats for only 23 miles, to the first falls. Rapids and falls occur at frequent intervals throughout its whole length and in travelling on it portages have frequently to be made. Its principal tributary is Tazin river, a stream of similar character rising near the north shore of Athabaska lake. The total length of Taltson river must be about 400 miles and its volume about 11,000 cubic feet per second. Tazin and Taltson rivers are important as they form the canoe routes for the Indians of Athabaska and Great Slave lakes to and from their hunting grounds on the edge of the Barren lands.<sup>4</sup>

Lockhart river rises in MacKay lake and flows successively through Aylmer, Clinton-Colden, Casba, and Artillery lakes to join Great Slave lake at its extreme eastern end. The connecting river between MacKay lake and Arthur lake has not been explored, but it is probably about 15 miles in length. From Aylmer lake to Casba lake the course lies entirely within the limits of the Barren lands and there are no obstructions to navigation. Between Casba lake, however, and Artillery lake, a distance of 15 miles, the stream falls 32 feet and in going up stream three portages have to be made, though only one is necessary going down. Artillery lake is 55 miles long and from there to Great Slave lake, 24 miles, Lockhart river falls 668 feet, so that it is nothing but a series of rapids and falls that follow each other in quick succession. The highest falls, called by Captain Back, Parry falls, have a drop of 85 feet into a rock-walled chasm that varies

<sup>1</sup>Geol. Surv., Can., vol. XII, 1899, pt. C.

<sup>2</sup>North American fauna, No. 27, U.S. Dept. of Agric., 1908, p. 108 et seq.

<sup>3</sup>Narrative of a journey to the shores of the polar sea in 1819-20-21 and 22.

<sup>4</sup>Camsell, C., Geol. Surv., Can., Mem. 84, 1916.

from 20 to 50 feet in width. There are five other falls ranging from 6 to 50 feet in height, which make the river quite unnavigable. In consequence of this the regular canoe route follows a chain of eight small lakes lying to the east of Lockhart river.<sup>1</sup> The total distance from the head of McKay lake to the mouth of Lockhart river is about 300 miles.

*Hoarfrost river* empties into Great Slave lake on the north side by a fall 60 feet in height at a point where the adjacent hills are about 1,000 feet high. The river has a very steep gradient and is full of rapids and falls. It rises in Walmsley lake and forms a difficult canoe route through that lake to Artillery lake, a route that was followed by Captain Back in 1833.<sup>2</sup>

### *Mackenzie River*

The name Mackenzie river is applied only to that portion of the Mackenzie River system extending from Great Slave lake to the Arctic ocean, a distance according to Ogilvie, of over 1,000 miles. The total distance, however, from the headwaters of the most distant tributary of Mackenzie river, namely the Finlay, to the Arctic ocean, is 2,525 miles.

The Mackenzie on issuing from Great Slave lake has a width of 7 or 8 miles, but is shallow and filled with islands between which a moderate current flows. Fifteen miles down, the islands cease and the river contracts to 4 miles. With a further decrease in width to 2 miles the strength of the current increases to about 4 miles an hour, until at Providence, 45 miles down, several islands block the channel and cause an acceleration of the current in what are called the Providence rapids. In these rapids the water, though swift, is quite smooth, and steamers have no difficulty in ascending them.

The country bordering the river below Great Slave lake is low and flat and the valley is shallow, with banks seldom exceeding 30 feet in height.

Below Providence the Mackenzie passes through an expansion known as Little lake where it receives the water of a fairly large stream from the north, Horn river, which rises in the rear of Horn mountain. Continuing westward it remains wide and sluggish as far as a point near Trout river known as the "Head of the line," so called because in ascending the river the sluggish current above permits travellers to discard the tracking line and use oars or paddles. Yellowknife river and Trout river, streams that are both reported to head in large lakes, are passed on the south side. The current increases its strength at the "Head of the line" and from that point to the mouth of the Liard, 75 miles, it continues very swift and the width of the stream is reduced to a little more than half a mile. The banks are here slightly higher and instead of sand and clay are composed of gravel and sand.

Simpson is situated on an island 2 miles long just below the junction of the Liard and the Mackenzie. The main channel of the river is here one mile wide and from this point northward to the Arctic the full width of the stream is rarely less than this.

From Simpson to the mouth of Nahanni river, a distance of 75 miles, the Mackenzie maintains its northwesterly direction. Its banks are about 200 feet high, with gravelly or bouldery beaches, and the current runs at an average rate of 4 miles per hour. Several groups of long low islands occupy this stretch and the only tributary large enough to be worthy of a name is Marten river which enters from the southwest 8 miles below Simpson.

<sup>1</sup> Tyrrell, J. W., Dept. of the Interior, Can., 1901, pt. III, p. 98.

<sup>2</sup> Back, Capt. G., "Narrative of Arctic land expedition in 1833-34 and 35."



At the mouth of Nahanni river the Mackenzie strikes against the base of Mackenzie mountains and being deflected sharply to the north by them, flows for several hundred miles parallel to and within sight of their peaks. Several low islands, the longest 20 miles in length, occupy the river bed below the Great Bend and behind one of these Root river enters from the west. A few miles farther Willow Lake river comes in from the east, and here the Mackenzie may be said to enter the mountains, for a range, low and wooded at first, but gradually increasing in altitude, rises out of the lowland on the east of the river and runs parallel to the river for about 200 miles. This range is known as the Franklin range.

At the site of old Fort Wrigley, which is about 20 miles below Willow Lake river, the Mackenzie is about  $1\frac{1}{2}$  miles wide, but below this point for 100 miles high hills press closely down on either side and confine the river to a channel free from islands and only about half a mile wide. The current here increases in strength and runs about 5 miles an hour.

The present position of Wrigley is 25 miles below the old site and almost opposite the Rock-by-the-river-side or Roche Trempe, l'eau, a steep, isolated, round-topped hill rising directly from the water's edge to a height of 1,500 feet. Below this point the west bank becomes high and the east bank lower, and no feature of interest occurs for about 30 miles, or until Blackwater river enters from the east. This stream is about 75 yards wide and is easily recognized by the great volume of clear, dark water that it discharges into the Mackenzie and which preserves its distinctive character for several miles before mingling with the water of the larger stream.

Two miles below Blackwater river the Mackenzie turns sharply to the west for 3 miles, below which it receives on the left a stream 100 yards in width. Salt river is 33 miles down on the right side and Gravel river 49 miles below Blackwater river. Gravel river is a mountain stream flowing in from the west and is frequently used by the Indians as a boat or canoe route from the mountains to the Mackenzie, but not in the reverse direction.

The Mackenzie expands again about Gravel river, enclosing a number of islands, and from this point to the Ramparts, a distance of 326 miles, the width of the stream is never less than a mile and frequently as much as 2 miles. The current varies in strength in different reaches but maintains an average of about 4 miles an hour, and the banks are from 100 to 400 feet in height.

A few miles above Norman, on the east side of the river, occasional columns of smoke indicate the presence of fires which are consuming the seams of lignite outcropping in the bank. Landslides occasioned by the burning out of the lignite seams and the undermining of the banks, occur at several points, and at others the shales are baked and reddened. These fires have been burning for at least one hundred and twenty-five years or since Alexander Mackenzie made the first exploration of the river in 1789.

Norman occupies a commanding position on the east bank of the river in the southern angle formed by the entrance of Great Bear river, and in the northern angle a steep, flat-topped mountain, known as Bear Rock, rises to a height of 1,400 feet almost directly from the water of the Mackenzie.

"From the mouth of Great Bear river the Mackenzie runs in a general west-northwesterly direction for 80 miles to Roche Carcajou, and then turns due west towards the East and West-mountains-of-the-rapid. In this distance it has an average width of over a mile and occasionally expands around islands to over 10

miles in width. Its current is at the rate of 3 or 4 miles an hour. Rugged limestone ranges are visible all along this reach on both sides of the river, but seldom approach within 30 miles of each other. The plains between and the lower slopes of the mountains are continuously clothed with forests of small spruce and aspen. The depression in which the river flows has a depth of from one hundred to four hundred feet and a width of from 2 to 3 miles. River flats are seldom present and the banks of the valley slope more or less steeply up from the edge of the water."<sup>1</sup>

Roche Carcajou is about 1,000 feet high and rises steeply from the water's edge. A weathered knob, which from a certain point of view resembles the figure of a wolverine, gives the name to the mountain.

Twenty-five miles below Roche Carcajou the river falls over a ledge of rock to form the Sans Sault rapid, which is the most important obstruction to steamboat navigation from Great Slave lake to the sea. In high water the rapid is drowned out, but in low water the fall is increased and becomes a more serious obstruction, although not sufficient to prevent the passage of steamboats. The river is divided by a channel part way down the rapid and the usual canoe route is down the western channel where the fall is more gradual than on the east side.

Below Sans Sault rapid the river is much expanded and has an average width of nearly 2 miles, but on approaching the Ramparts it suddenly contracts to about 500 yards in width and bending to the east runs for about 7 miles between vertical cliffs of rock. At the upper end of the Ramparts these cliffs are 125 feet high, but increase towards the lower end to about 250 feet. The current in the Ramparts runs at a rate of 4 or 5 miles an hour and in low water a somewhat formidable rapid occurs near the upper end. The water throughout is deep and at the head of the Ramparts was found by Alexander Mackenzie to be 300 feet in depth.

Good Hope is situated on the right bank of the Mackenzie about 2 miles below the Ramparts and only a few miles south of the Arctic circle. The site has been occupied since 1836.

Hare Indian river enters from the east 3 miles below Good Hope, and Loon river 21 miles farther. For the next 100 miles the Mackenzie maintains a northwesterly course and is never less than a mile in width and in what is known as the Grand View is about 3 miles wide. The valley is shallow and the river has many islands.

In about latitude 67° 30' the river turns westward at right angles to the course it has previously been following and continues in this direction for about 60 miles, between high clay banks. The current here runs from 2 to 3 miles an hour. The country on either side is low and flat and no mountains are visible in any direction.

At the end of the western reach the river resumes its northwesterly course and its valley becomes deeper and more contracted for some miles, resembling a wide canyon. This has received the name of Lower Ramparts or the Narrows. The river here is half a mile wide at its narrowest point, but for most of the distance exceeds a mile in width. There is no sign of a rapid and the current is nowhere more than 5 miles an hour.

Arctic Red river enters from the west immediately below the Narrows and at its mouth is situated the trading post of the same name. Twenty miles below this Mackenzie river begins to spread out in its delta.

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<sup>1</sup> McConnell, R. G., Geol. Surv., Can., vol. IV, 1888-89, p. 102 D.

The delta of the Mackenzie extends in a north and south direction for about 100 miles and has a spread across its seaward side of about 70 miles. On the west the steep fault scarp of Richardson mountains rises abruptly out of the delta plain, and on the east it is bounded by a lower, rounded range known as the Reindeer hills. Peel river joins Mackenzie river at the head of the delta and branches of both streams ramify in all directions through it, forming islands which usually contain many lakes. The banks are low, built of alluvial material, and forested with spruce and willows. Northward the banks gradually diminish in height and the forest growth decreases and finally disappears. Little is known of the depth of the water in the various channels of the delta, but Count de Sainville found a channel in the main eastern branch with not less than 5 feet anywhere throughout its length.

The Mackenzie is characterized by the comparative purity of its water, and since for its size it carries relatively little sediment its delta is not being built up as rapidly as that of its great counterpart, the Mississippi.

The great lakes within its drainage basin act not only as sedimentation basins, but also serve to regulate the flow of the stream. Its volume, therefore, does not vary very greatly at different seasons of the year. According to some rough measurements made by McConnell the discharge at a medium stage of water is about 500,000 cubic feet per second.

The average grade of the stream for over 1,000 miles from Great Slave lake to the Arctic ocean is about 5 inches to the mile and at no point does it greatly exceed this.

#### *Liard River*

Liard river is one of the main tributaries of the Mackenzie. Like the Peace, it has its sources west of the Rocky mountains and after uniting into one master stream cuts a deep canyon-like valley as it flows eastward through those mountains. In its upper part it is divided into four nearly equal streams, namely the Kachika or Mud river, Dease river, Frances river, and the branch which retains the common name, streams which interlock with the headwaters of Peace, Skeena, Stikine, and Yukon rivers. It is a particularly rapid and dangerous stream having a fall between Dease lake and the Mackenzie of about 2,300 feet, giving an average grade to the stream of over 3 feet to the mile. The descent of the river is greatest and its rapids most numerous while passing through and for some distance on either side of the Rocky mountains.

West of the Rocky mountains Liard river and its tributaries flow through an irregular, forested plain, relieved at intervals by short disconnected ranges of hills. Dease and Frances rivers, and the Liard above the mouth of the Dease, are all swift-flowing streams, and navigable with difficulty even in ordinary stages of water. Below the mouth of the Dease and as far as Rivière des Vents, which is at the western base of the Rockies, the river is many times closely canyoned in and broken by rapids. The most formidable of these, namely Little Canyon, Cranberry rapids, Mountain Portage rapids, and Brûlé rapids, can be overcome only by portages varying in length from one-half to 2 miles.

In its course through the Rocky mountains and the eastern foothills the Liard is navigable only by canoe, and that with difficulty and considerable danger. In descending the river the first obstruction encountered in this portion is Devils rapids, where the river makes a wide bend to the northeast, all around which is a succession of rapids and canyons. At the lower end of the bend the

river is reduced to a width of about 70 feet between rock walls. The portage trail across the bend is 4 miles in length and runs over a ridge 1,000 feet in height.

"Below the Devils portage for 30 or 40 miles the river flows through what is called the Grand canyon, but is more correctly a succession of short canyons, with expanded basins between filled with eddying currents. In low water the whole of this reach can be easily run in almost any kind of a boat, but in the season of high floods . . . . the water forcing its way through the throat-like contractions is thrown into a commotion too violent for any but the staunchest boats to stand. The canyon is reported to have been run in two hours, which would be at the rate of about 18 miles an hour, an astonishing velocity, but the time was probably underestimated."<sup>1</sup> The last of the constrictions in Grand canyon is known as Hell Gate because it forms the entrance from below to the wild portion of the river.

Shortly below Hell Gate the Liard breaks through the foothills and enters the Great Central plain, in which it has an uninterrupted flow and presents no obstacles to navigation until near its mouth. Its principal tributaries on the north are Beaver and South Nahanni rivers, both streams flowing from Mackenzie mountains and as yet little known. On the south are Fort Nelson river a comparatively easy-flowing stream from 150 to 200 yards wide at its mouth, and Black river, a smaller stream draining a lake country to the southeast.

Below Fort Liard the river flows in a shallow valley often filled with islands and its current runs about 4 miles an hour. Within 30 miles of the Mackenzie, however, the valley deepens and takes on the appearance of a wide canyon. The current becomes swift and for nearly 10 miles breaks over a succession of riffles. These are all easily run in a canoe by keeping close to the right bank, but will form a rather serious obstacle to navigation of the river by steamboats.

Before joining the Mackenzie the river expands to a width of nearly 2 miles, much of which, however, is occupied by islands and sand-bars.

### *Great Bear River*

Great Bear river<sup>2</sup> carries the water of Great Bear lake to the Mackenzie in a stream about 90 miles in length. It issues from the lake in a broad, shallow channel with a swift current which it maintains throughout its course. It is confined throughout most of its length between banks of sand or clay and is 150 to 350 yards in width.

About half-way down its course it cuts through Franklin mountains and in doing so forms a rapid nearly 3 miles in length. This, however, is easily navigable for canoes in all stages of water by following the right hand shore, but by its shallowness presents considerable difficulties for steamboats. Below the rapid the river expands and its current is not so swift.

The water of Great Bear river is beautifully clear and of a greenish-blue colour, particularly noticeable when contrasted with the main stream at its junction.

### *Peel River*

The sources of Peel river and its upper tributaries lie on the northern and western slopes of Mackenzie mountains. The main stream occupies a great bay

<sup>1</sup> McConnell, R. G., Geol. Surv., Can., vol. IV, 1888-89, p. 47 D.

<sup>2</sup> Bell, J. M., Geol. Surv., Can., vol. XII, pt. C.

in the mountains and flows eastward as far as Snake river; its principal tributaries join it from the south. At Snake river it swings to the north and continues in that direction to its junction with the Mackenzie.

Peel river has not been explored above the mouth of Wind river, but its course is said to be interrupted by falls about 30 miles above that point.

Wind river is a rapid, shallow stream with a discharge of about 5,000 cubic feet per second rising near the headwaters of Stewart river. It forms part of a difficult canoe route from Yukon river to Mackenzie river.<sup>1</sup>

Peel river is in a canyon at the mouth of the Wind, but a mile below expands to a width of nearly a mile. Seams of lignite are burning in this expanded portion, which extends for 15 miles down to the lower canyon. Bonnet Plume river, which enters from the south 3 miles above the canyon, is an unexplored river which at its mouth appears to be slightly larger than the Wind.

The lower canyon of the Peel is 2 miles long and about 500 feet deep, with a current that runs from 6 to 8 miles an hour. It is formed by a low range of hills crossing the river at this point. Below this the river runs for 158 miles through the Peel plateau, cutting a valley which averages about 800 feet in depth. The current is strong throughout, but no rapids occur.

Snake river is the largest tributary of the Peel, having a discharge considerably greater than the Wind river, and a width at the mouth of about 350 feet. It is said to be navigable for canoes for a long distance above the Peel.

At Satah river the Peel emerges from the plateau and enters the lowland of the Mackenzie, where the banks decrease in height to about 100 feet and the strength of the current is reduced to about 2 miles an hour.

At Fort McPherson the Peel has a discharge in a medium stage of water of about 40,000 cubic feet per second and a velocity of about 2 miles per hour. This is the highest point to which steamers ascend the river, but there seems no reason why stern-wheel boats can not ascend the stream as far as the mouth of Wind river.

Shortly below Fort McPherson the Peel enters the delta of the Mackenzie and although its eastern branch joins the Mackenzie 24 miles below the Fort, the extreme western branch, locally known as Huskie river, does not do so for about 100 miles more.

#### *Other Tributaries of Mackenzie River*

Between Great Slave lake and the mouth of the Liard the Mackenzie receives a number of tributaries, but they are almost all unexplored beyond their mouths. On the southwest side are Beaver, Yellowknife, and Trout rivers, all of which are said to drain a lake country and to descend from the Alberta plateau to the Mackenzie lowland in a fall or series of falls. On the northeast side, the most important stream is Horn river which flows through a series of lakes to join the Mackenzie at Little lake. It is about 50 yards wide at the mouth and is navigable for canoes for a long distance, but heavy rapids are stated to occur in its upper part. Other streams on this side are Spence and Rabbitskin rivers, both as yet unexplored.

The important streams entering the Mackenzie between the Liard and Great Bear river are Nahanni, Root, Dahadinni, and Gravel rivers on the west side and Willow Lake and Blackwater rivers on the east, all of which, with the exception of the Gravel, are unexplored beyond their mouths.

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<sup>1</sup> Camsell, C., Geol. Surv., Can., "Peel river and tributaries," 1906.

Gravel river is described by J. Keele<sup>1</sup> as a swift mountain stream cutting across the ranges of Mackenzie mountains and entering Mackenzie river through a broad, alluvial flat. A rough measurement on July 19, 1908, above its mouth gave a width of 700 feet and a discharge of 25,000 cubic feet per second. It is used by the Indians as a boat route from the mountains to the Mackenzie.

Below Great Bear river the tributaries of importance are Carcajou, Hare Indian, and Arctic Red rivers.

Hare Indian river heads near Great Bear lake and was partly explored by MacFarlane<sup>2</sup> in 1857. At its mouth it is about 200 yards wide and it retains that width for a long distance.

Arctic Red river is about 200 yards wide at its mouth and though shallow is said to be navigable for canoes for a considerable distance. It has, however, not yet been explored.

### *Tributaries of Great Bear Lake*

The country surrounding Great Bear lake is very imperfectly known and at present only two streams flowing into the lake, namely Dease and Camsell rivers, have been described.

Camsell river<sup>3</sup> enters an inlet on the south side of McTavish bay and drains a large part of the rocky Laurentian plateau to the south. It is important as forming part of the Indian canoe route from Great Bear lake to Great Slave lake. Its course is through a number of lakes and is broken by many rapids and falls so that it is only navigable for canoes by making numerous portages.

Dease river,<sup>4</sup> which discharges into the northeastern arm of the lake, is important only because it forms a difficult canoe route to Coppermine river. It rises in the treeless country between Dease bay and Coppermine river, and is a shallow, rapid stream not easily navigable even for canoes.

## GREAT LAKES

### *Athabaska Lake*

Athabaska lake, the southernmost of the great lakes of the Mackenzie basin, is a long and comparatively narrow sheet of water extending in an east-northeasterly direction. It has a length of 195 miles, a greatest width of about 35 miles, and a shore-line of over 520 miles, embracing a total area of about 2,900 square miles. It occupies a great depression excavated along the line of contact between horizontal Keweenawan sandstones and the Precambrian schists and gneisses. Its surface stands at an elevation of 695 feet above the sea, but its depth has never been determined.

The south shore of the lake is fairly direct and rises more or less abruptly to a great sandy plain, the maximum height of which is 500 feet above the lake level. The north shore is rocky, very much indented by bays, and fringed by hundreds of islands. The country to the north of the lake is composed of irregular rocky hills which at Black bay reach a height of 800 feet above the lake. The divide between Athabaska lake and Great Slave lake is only a few miles north of the former and consequently there are few streams flowing

<sup>1</sup> Geol. Surv., Can., "A reconnaissance across the Mackenzie mountains." 1910.

<sup>2</sup> Can. Rec. of Sc., Jan., 1890.

<sup>3</sup> Bell, J. M., Geol. Surv., Can., vol. XII, pt. C.

<sup>4</sup> Hanbury, D. T., "Sport and travel in the northland of Canada."

into it from the north and all are short, rapid, and unnavigable. On the south side the streams, though larger, are small, and none of them is navigable by canoes for any great distance except Old Fort river. The principal inflowing streams are Stone or Black river at the east end, and Athabaska river at the west end. In periods of flood Peace river also flows into the lake by way of Quatre Fourches river, but normally this and the Rocher river are outflowing streams.

Athabaska lake formerly extended much farther west over the basins of lake Mammawee and lake Claire, but Peace and Athabaska rivers have gradually built up deltas at their mouths and cut off these two lakes from the main lake.

Towards the eastern end of the lake the water is clear and pure, but at its western end it is rendered turbid by the material discharged into it by Athabaska river.

Athabaska lake is usually not free from ice until the middle of June and it begins to freeze over again early in October. The western end, however, at the mouth of Athabaska river, is usually open early in May.

#### *Great Slave Lake*

Great Slave lake, according to Cameron,<sup>1</sup> has a superficial area, including islands, of over 12,000 square miles and ranks fourth among the great lakes of the continent, being exceeded in size only by Superior, Huron, and Michigan. No complete survey of the shores has yet been made, but the lake is estimated to have a total length of 288 miles and its greatest width exceeds 60 miles.

Originally it had the form of a great cross, with one arm penetrating eastward into the Laurentian plateau, two others stretched north and south along the contact between the Laurentian plateau and the horizontal sedimentary rocks of the lowland, and the fourth extended westward over the flat-lying rocks of the lowland. The southern arm extended southward up the valley of Slave river, but has now been silted up by the material carried in by that stream.

The eastern portion of the lake has a very irregular outline and is dotted by numerous rocky islands. Its shores are bold, rocky, and sparsely wooded, and on the north side rise in places to a height of 1,000 feet above the lake. Into the north side, Hoarfrost river precipitates itself over a precipice 60 feet in height, and at the east end Lockhart river enters, after flowing from Artillery lake in a series of rapids. On the south side the only tributary of importance is Taltson river which enters near Slave river and drains most of the region between this arm of the lake and Athabaska lake.

The northern arm of the lake is over 100 miles in length, but is narrow and filled with islands. Its shores are rocky and are nowhere very high. Yellowknife and Grandin rivers are the only important streams discharging into it and neither is navigable except for canoes.

The western arm presents a greater expanse of water, unbroken by islands, than either of the other divisions. "Its southern shore has a gentle, sinuous outline and is characterized by low banks and gently shelving beaches which are often thickly strewn with boulders. The banks . . . are often built up of drift timber. The northern shore is more uneven and is indented with several deep bays."<sup>2</sup> This arm is bordered on both sides by a flat, wooded country, which on the south side rises inland a few miles to some low rounded hills.

<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1916.

<sup>2</sup> McConnell, R. G., Geol. Surv., vol. IV, 1888-89, p. 66 D.

The water of Great Slave lake in the east and north arms is clear and probably deep. In the west arm, however, it is shallow and never entirely clear, as some of the sediment brought down by Slave river remains in suspension and drifts slowly westward towards the head of Mackenzie river.

Ice forms in the lake along the shores about the middle of October, but the middle of the lake frequently remains open until the end of November. In the spring, channels open along the shore early in June, but in the main body of the lake ice often remains until July 1 and in the east arm until somewhat later.

### *Great Bear Lake*

Great Bear lake is the next largest of the great lakes of the Mackenzie basin, having an area of about 11,400 square miles. Its shores have never been completely or accurately surveyed and for its delineation we are indebted mainly to Sir John Richardson<sup>1</sup> in 1825 and 1826 and to J. M. Bell<sup>2</sup> in 1900. It is very irregular in shape and is formed by the union of five arms in a common centre. Its greatest diameter from east to west is about 170 miles, and in a northeasterly direction from the bottom of Keith bay to the end of Dease bay is about the same distance. The greatest depth of water in the lake has never been ascertained, but in Smith bay a sounding by Bell<sup>3</sup> with 281 feet of cord did not reach bottom, and Richardson<sup>4</sup> states that 45 fathoms of line did not reach bottom in McTavish bay.

The shores of the lake are in general low. Ranges of hills approaching 1,000 feet in height, however, occupy the peninsula between McVicar and Keith bays and that between Richardson bay and Smith bay. The shores of McTavish bay too are bold and rocky, often rising sheer out of the water for hundreds of feet. "The southern and western shores are well wooded, while its northern and eastern borders are more thinly forested. The immediate shores are mainly of sand and gravel and are usually devoid of trees, but are well clothed with willows and various ericaceous shrubs and herbaceous plants. In most places along the south shore this treeless stretch is only a few hundred yards in width, and in the bays the forest extends to the water's edge."<sup>5</sup>

The drainage basin of the lake is small in comparison with the size of the lake itself and there are consequently few streams flowing into it, all of which are short and rapid. Dease river at the extremity of Dease bay and Camsell river at the southeast corner of McTavish bay are the best known tributaries.

The water of Great Bear lake is light bluish in colour and so clear and transparent that Richardson states a white rag dropped into the water was visible until it reached a depth of 90 feet.<sup>6</sup>

Ice forms along the shores of the lake and in the bays early in October, but the centre of the lake is not frozen over until the beginning of December. The outlet of the lake, however, frequently remains open throughout the winter. By the middle of June the ice begins to break up along the shores, but drift ice sometimes obstructs navigation in the main body of the lake until the end of July.

<sup>1</sup> Narrative second expedition to polar sea, Appendix, 1828.

<sup>2</sup> Geol. Surv., Can., vol. XII, pt. C, 1899.

<sup>3</sup> Geol. Surv., Can., vol. XIII, 1900, p. 99 A.

<sup>4</sup> Op. cit., p. ii.

<sup>5</sup> Preble, E. A., North American fauna, No. 27, U.S. Dept. of Agric., 1908, p. 43.

<sup>6</sup> Narrative second expedition to polar sea, Appendix, p. ii, 1828.



*Other Large Lakes*

Other lakes large enough to be of considerable importance though not large enough to be classed with the great lakes, are lake MacKay, Aylmer and Clinton-Colden lakes, and lac La Martre.

Lake MacKay is situated north of Great Slave lake on the edge of the Barren lands. It was discovered by Warburton Pike<sup>1</sup> in 1890 and estimated by him to be about 100 miles in length, though he saw only about 50 miles of it. The lake is cut by a number of long points and has numerous islands. The south shore is sparsely timbered, and the north shore is entirely devoid of timber. The shores are all rocky and the hills at the northeast end are grouped in a regular range.

Aylmer and Clinton-Colden lakes<sup>2</sup> are separated from each other by only a narrow strait, known as the strait of the Sandhill. Their combined length is said to be about 100 miles and the greatest width 30 miles. The shores are low and shelving, 80 to 100 feet high, and islands are numerous. Both shores are practically devoid of timber, for both the lakes are situated within the limits of the Barren lands.

Lac La Martre northwest of Great Slave lake is also one of the larger lakes, but its general character and surroundings have never been described by any writer.

Lesser Slave lake is 61 miles long and has a maximum width of 12 miles, embracing an area of 484 square miles. It is very shallow and seldom exceeds 10 feet in depth at low water.

## AGRICULTURE

The division of the whole basin of Mackenzie river into three great physiographic provinces, namely, the Laurentian plateau on the east, the Cordillera on the west, and between them the Great Central plain, makes it possible to delimit the possible agricultural portion of the basin from that which is impossible of cultivation.

The Laurentian Plateau portion which forms about one-fifth of the whole basin and which is outlined on the accompanying physiographic map (Figure 1), because of its rocky character, its absence of soil, and its low average temperature, is not generally suitable for agricultural purposes and can never be considered as part of Canada's reserves of agricultural lands. Except in a few localities where areas of clay land occur or where deposits of alluvium have accumulated no crops of any kind are at present being raised within the limits of this portion of the basin. Such localities are Chipewyan and Fort Smith where excellent crops of garden vegetables and some hardy grain are grown. These localities, however, are so close to the border of the Great Central plain as to partake very largely of the characteristics of that region.

In the Cordilleran portion of the basin only a very small proportion can be considered to have any agricultural possibilities, and this is confined to the main valleys such as the Peace and Athabaska and to the lower branches along these valleys.

The Great Central plain of the Mackenzie basin is pre-eminently that portion of the basin best adapted to agricultural pursuits (Plate VI). This portion constitutes about one-half of the whole basin, but it must not be assumed that the

<sup>1</sup> Barren grounds of northern Canada, 1892, p. 58.

<sup>2</sup> Back, Captain, "Arctic land expedition, 1833-34-35," p. 138.

King, Richard, "Narrative of a journey to the Arctic ocean," p. 138.

whole of it is occupied by cultivable land. So far as our incomplete knowledge of the country will allow us to draw any conclusions it may be said that the northern limit to which cultivation of the land may proceed in a large way is the line formed by Great Slave lake, Mackenzie river to the mouth of the Liard river, and Liard river up to the mountains. This is approximately along the line of latitude 61 degrees north.

North of this line excellent crops of garden vegetables (Plate V) and barley have been raised along the valley of the Mackenzie at Wrigley and Norman, and even as far north as Good Hope on the edge of the Arctic circle. Similar crops might be grown in favourable localities in the country back from the river. In general, however, it may be said that the greater part of this portion of the basin inland from the streams is made up of spruce muskegs with little or no drainage and a permanent frost only a few inches beneath the surface, which would make farming impossible.

South of Great Slave and Liard river is an area within the Mackenzie basin covering about 200,000 square miles of the Great Central plain, which from the operations that have been carried on for years at the various trading posts of Fort Nelson, Fort Liard, Simpson, Providence, Resolution, Fort Smith, and Fort Vermilion, we know to be capable of supporting a population mainly by agriculture wherever the soil is suitable. Parts of this region are no doubt too high above sea-level and other areas are low-lying spruce muskegs incapable of drainage, and cannot be considered as possible agricultural land. How great a part of this 200,000 square miles is to be considered unsuitable it is impossible to say, but it is no doubt large. The best part of it is believed to be that portion immediately adjoining the Peace river and its tributaries, especially Smoky river, and referred to generally as the Peace River country.

Within the limits of the Peace River country it has been estimated that there are areas totalling in all some 10,000,000 acres of prairie or slightly wooded country on which crops of vegetables and hardy grains can be successfully grown. The remainder of the country is more heavily wooded with poplar, spruce, or jackpine, and although the soil and climatic conditions are similar to those which obtain in the prairie portions it will necessarily be more difficult to clear and much longer before it is taken up by settlers.

Of the Peace River region the northern area which centres about Fort Vermilion is apparently the most generally favourable for agriculture. Though more than two degrees farther north than Peace River Crossing, where so much settlement is now going on, the climatic conditions seem to be somewhat more favourable, due no doubt to the lower altitude, the country about Vermilion being about 1,000 feet above the sea and the plateau behind Peace River Crossing at least 1,000 feet higher still.

Fort Vermilion is the centre of a small farming community in which virtually all the vegetables, wheat and other grains, and meat necessary for the support of the community are produced. Only a small proportion of the arable land is, however, cultivated, because lack of transportation facilities prevents the farmers from getting their produce to a market.

In the upper Peace River region an active immigration of settlers has been going on for the last few years. Land is being taken up about a number of centres, mainly about Grande Prairie, Spirit River, Peace River Crossing, and Dunvegan. Both farming and ranching are successfully carried on and since the entry of the Edmonton, Dunvegan, and British Columbia railway into that region in the summer of 1915 the settlers are able to sell their produce in the

markets of the world. In this region there is said to be about 1,000,000 acres of actual prairie land and by the summer of 1916 practically all of this had already been taken up in homesteads, leaving only the partly or wholly wooded country for the future homesteader.

In the basin of Athabaska river agricultural communities are growing about Lesser Slave lake, Athabaska, lac la Biche, and McMurray, all of which except McMurray are already served by railways. Most of this country is, however, a forested region, the percentage of prairie being much smaller than in the Peace River country, consequently development will be much slower. The crops grown in these localities are mainly vegetables and the hardier grains, just as in the Edmonton district. Mixed farming is generally practised throughout the whole district, but, as in the Peace River country, only a small proportion of the total available is as yet taken up.

Farming and ranching operations on a small scale are being undertaken by the Roman Catholic Mission on Salt plain (Plate VI), a few miles west of Fort Smith. In this region there are several thousand acres of prairie or partly open country covered with a variety of fodder grasses, making an excellent range for horses and cattle. It originally formed a part of the range of the wood buffalo, but is now overrun by the horses of the residents of Fitzgerald and Fort Smith, which winter out on the plain. The Mission in 1916 had about 100 head of cattle and a few horses, and ground has been broken on which a variety of vegetables, barley, and oats have been successfully grown.

#### CLIMATE

Since the basin of Mackenzie river extends over about 17 degrees of latitude its climate is necessarily of such variety that it cannot be discussed satisfactorily in a general way. The summer climate of the Mackenzie basin, however, is not so much governed by latitude as the winter climate, for the isotherms for summer run in a northwesterly direction almost parallel to the length of the basin indicating a uniformity of temperature in that direction. The 55 degrees summer isotherm, for example, runs from Kenora on lake of the Woods northwesterly to the east of lake Winnipeg and thence through the east end of lake Athabaska, the middle of Great Slave lake, and the west end of Great Bear lake to Good Hope on the Arctic circle where it swings west into the mountains. The isotherms for the year, however, show a closer coincidence with the lines of latitude and indicate a decrease in temperature with an increase in latitude. This is due not so much to lower extremes of temperature in the northern latitudes as to a longer period of low temperatures in those regions throughout the year. The high latitude of, for example, Simpson at the mouth of Liard river, means a long cold winter and a short but warm summer. It involves also, however, a great increase in the amount of possible sunshine during the important growing period from May 15 to August 15. Compared with Ottawa, Simpson has an average of three hours more sunlight daily for the summer months, which means about eighteen days of additional sunshine during the three months when sunshine is most important.

In general it may be said that any point in the Mackenzie basin has a milder climate than any corresponding point of the same latitude in northern Manitoba, Ontario, or Quebec, probably because it is farther removed from the chilling influence of the large body of water, frozen for a great part of

the year, contained in Hudson bay; also because it comes within the sphere of influence of the warm winds from the Pacific, and because of its soil covering.

Precipitation is fairly uniform throughout the whole basin and is nowhere excessive. It is in general slightly higher than that which obtains on the prairies of Alberta and Saskatchewan, but nowhere as heavy as it is on either the Atlantic or Pacific coasts. The total precipitation ranges between 15 and 20 inches annually and the snow in the central portion of the basin lies usually to a depth of about 2 feet. Snowfall is somewhat greater in the mountains to the west where the total precipitation too is higher.

The whole basin is wooded and although storms and blizzards occur occasionally they are by no means as violent as they are on the prairies because of the protection of the forests.

The great inland bodies of water, Athabaska, Great Slave, and Great Bear lakes, have a large influence in lowering summer temperature and retarding the advance of spring in the country adjacent to them because ice remains in them until late in June and in the northern lakes even until July. On the other hand, the influence of the warm winds from the Pacific in raising the temperature is felt along the eastern slopes of the mountain as far north as Liard river. These winds, commonly known as chinook winds, are particularly noticeable in the upper Peace River country and frequently bring warm waves during the winter months sufficient to melt the snow. They are not so prevalent in the summer months, but it was noticed by Dr. G. M. Dawson in the Peace River country in 1879, that summer frosts usually occurred on calm clear nights following a high wind from the west.

Temperatures during the day, even as far north as the delta of the Mackenzie, occasionally reach a maximum of about 85 degrees F. during the months of June, July, or August, but there is usually a decided drop as soon as the sun goes down. The nights, therefore, are always cool, with the temperature rarely above 50 degrees F., and except in the southern portion of the basin it is liable to descend below the freezing point at any time of the year. During the winter the lowest temperatures occur in the month of January, when the thermometer occasionally drops in the southern part of the basin to 45 degrees below zero and in the northern part to 60 degrees below.

For the purpose of comparing the climate in different parts of the basin, the following tables of temperatures for the year, at a few widely separated points, are submitted. Those for Athabaska, Peace River Crossing, Fond du Lac, and Resolution are for the year 1912, and those for Simpson and Good Hope are for 1900.

*Mean Daily Maximum*

Month	Athabaska	Peace River Crossing	Fond du Lac	Resolution	Simpson	Good Hope
January.....	8.7	2.9	-16.2	.....	-16.2	
February.....	28.3	24.2	- 3.4	.....	- 9.2	
March.....	32.5	34.7	7.5	.....	12.8	
April.....	51.7	52.5	32.9	30.3	41.2	
May.....	65.6	70.0	50.3	53.7	52.6	
June.....	76.7	75.4	66.9	66.8	69.3	
July.....	68.5	71.6	66.5	63.6	69.4	
August.....	69.6	72.1	.....	66.3	65.0	
September.....	62.5	63.9	.....	57.2	56.8	
October.....	51.1	49.8	38.8	38.8	29.0	
November.....	36.6	32.7	25.5	21.0	5.4	
December.....	28.7	19.7	5.5	- 0.6	- 7.3	
Year.....	48.4	47.5	.....	.....	30.7	

*Mean Daily Minimum*

Month	Athabaska	Peace River Crossing	Fond du Lac	Resolution	Simpson	Good Hope
January.....	- 9.7	-18.3	-33.2	.....	-33.5	
February.....	3.6	- 2.1	-20.8	.....	-33.5	
March.....	- 1.0	- 3.8	-18.1	.....	-17.4	
April.....	27.7	27.0	11.0	11.7	17.8	
May.....	34.0	35.7	29.7	30.0	35.2	
June.....	42.8	44.0	46.5	46.6	45.3	
July.....	43.0	44.5	47.0	45.7	45.7	
August.....	46.8	45.4	.....	49.6	44.1	
September.....	31.3	32.8	.....	39.9	34.7	
October.....	26.4	25.4	28.9	29.9	19.2	
November.....	17.9	13.4	12.7	12.8	- 8.7	
December.....	5.3	- 1.5	- 2.8	-14.1	-20.1	
Year.....	22.3	20.2	.....	.....	10.7	

*Extreme Maximum*

Month	Athabaska	Peace River Crossing	Fond du Lac	Resolution	Simpson	Good Hope
January.....	39	33	12	.....	5.0	11
February.....	45	44	10	.....	14.0	6
March.....	55	57	26	.....	39.0	24
April.....	65	64	51	54.0	60.0	48
May.....	87	89	67	77.0	66.0	56
June.....	93	93	90	88.0	80.0	80
July.....	83	88	79	77.0	79.5	83
August.....	81	88	.....	79.5	78.0	75
September.....	81	82	.....	78.0	71.0	60
October.....	75	68	64	55.0	40.0	34
November.....	51	49	36	39.0	23.0	21
December.....	52	49	18	16.0	13.0	- 6
Year.....	93	93	.....	88.0	80.0	83

*Extreme Minimum*

Month	Athabaska	Peace River Crossing	Fond du Lac	Resolution	Simpson	Good Hope
January.....	-47	-53	-51	.....	-51.0	-62
February.....	-34	-33	-34	.....	-50.5	-46
March.....	-28	-30	-37	.....	-50.0	-47
April.....	21	17	-13	-13.0	5.0	-20
May.....	22	26	18	12.0	27.0	14
June.....	25	29	31	34.0	27.0	29
July.....	30	34	37	32.5	31.5	39
August.....	29	29	.....	35.0	27.0	23
September.....	18	17	.....	25.0	23.0	12
October.....	8	8	15	13.0	3.0	-22
November.....	-3	-6	-11	-8.0	-29.0	-47
December.....	-30	-37	-20	-32.0	-48.0	-50
Year.....	-47	-53	-51	.....	-51.0	-62

*Monthly Mean*

Month	Athabaska	Peace River Crossing	Fond du Lac	Resolution	Simpson	Good Hope
January.....	-0.5	-7.7	-24.7	.....	-24.8	-35.7
February.....	16.0	11.1	-12.1	.....	-21.4	-26.1
March.....	15.8	15.5	-5.3	.....	-2.3	-7.6
April.....	39.7	39.8	22.0	21.0	29.5	19.5
May.....	49.8	52.9	40.0	41.9	43.9	37.2
June.....	59.8	59.7	56.7	56.7	57.3	56.6
July.....	55.8	58.1	57.0	54.7	57.6	59.6
August.....	58.2	58.8	.....	58.0	54.5	49.2
September.....	46.9	48.4	.....	48.6	45.7	37.9
October.....	38.8	37.6	33.9	34.4	24.1	12.3
November.....	27.3	23.1	19.1	16.9	-1.7	-15.9
December.....	17.0	9.1	1.4	-7.4	-13.7	-24.3
Year.....	35.3	33.9	.....	.....	20.7	13.6

The freezing and breaking up of the rivers and lakes are events intimately connected with the climate and therefore of interest in that connexion. In all the rivers of the Mackenzie basin navigation is interrupted by drift ice in the autumn some time before the actual closing of the streams; and in the spring ice-cakes continue to run for several days after the breaking up of the rivers.

Athabaska and Peace rivers break up between the middle and the end of April, and ice may be expected to run in these streams any time after the middle of October, though it may be as late as the middle of November.

Liard river is a week or ten days later in breaking up in the spring and a few days earlier when ice begins to drift in the autumn. The ice from the Mackenzie below the mouth of the Liard is disrupted in spring through the influence of the Liard river, but it is usually from two to three weeks before the break reaches the head of the delta of the Mackenzie. The Mackenzie above the mouth of the Liard generally remains solid for a week or ten days after the ice breaks up below that point.

Ice remains in Athabaska lake until about the middle of June, in parts of Great Slave lake until the early part of July, and in Great Bear lake until somewhat later. In the autumn, ice begins to form in the bays and sheltered parts of the great lakes early in October, but on account of storms the main bodies of the lakes remain open for several weeks after. The small inland lakes and muskegs are frozen by the end of October in the southern part of the basin and about a month earlier in the northern part. There is a difference, also, of about a month, between the southern and the northern parts of the basin, in the disappearance of the winter snow in the spring and the breaking up of the ice in the streams.

## FAUNA

Because of its wide range in latitude and the diversity of its topographic features the basin of Mackenzie river contains a great variety of game and fur-bearing animals and birds, besides several species of food fishes.

Moose (*Alces americanus*) are found throughout the whole region northward to the mouth of the river and eastward to the limit of trees. They are, however, more numerous in the central and mountain portions of the region than in the rocky Laurentian plateau to the east.

Barren-ground caribou (*Rangifer arcticus*) are abundant at different seasons of the year in different parts of the eastern border of the basin, both in the Barren grounds and the forested country bordering them. They are in the main migratory in their habits and travel southward to the shelter of the woods in the autumn and north again in the early spring.

Woodland caribou (*R. caribou*) are not abundant anywhere and their range extends northward only to about latitude 62 degrees, but the mountain caribou (*R. caribou montanus*) are found in the Rockies and in the Mackenzie mountains as far north as Gravel river.

Mountain sheep of three varieties (*Ovis canadensis*, *O. stonoi*, and *O. dalli*) occur throughout the Cordilleran region, *Ovis dalli*, however, being confined to Mackenzie mountains, *Ovis stonoi* to the Rockies about the head of the Liard river, and *Ovis canadensis* to the south of this.

Mountain goat (*Oreamnos montanus*) range throughout the Rocky mountains and are said to be found also in the southern part of Mackenzie mountains.

Muskox (*Obivos moschatus*) are confined to the barren grounds and are now even being restricted to the more inaccessible parts of that region. Within the Mackenzie watershed they occur now only about Aylmer and Clinton-Colden lakes.

Wood bison or buffalo (*Bison athabascæ*) formerly ranged over much of the country from Athabaska river to the Liard, but are now restricted to a few herds embracing some hundreds of individuals which inhabit the region west of Slave river (Plate VII) and north of the Peace.

The black bear (*Ursus americanus*) occurs more or less abundantly throughout the whole region and its range is coextensive with the forest.

Grizzly bears (*Ursus horribilis*) are found throughout Rocky, Mackenzie, and Richardson mountains as far north as the delta of the Mackenzie.

The barren-ground bear (*Ursus richardsoni*) frequents the Barren grounds, but is not uncommon in the wooded country on the north and south shores of Great Bear lake.

The skins of polar bears (*Thalarctos maritimus*) are frequently obtained by the furtraders at the trading posts at the mouth of the Mackenzie, but the range of this animal is restricted to the coast and islands of the Arctic sea.

The basin of Mackenzie river is still the best fur producing part of the North American continent and a great many of the high-grade furs are obtained from it. These include beaver (*Castor canadensis*), muskrat (*Fiber zibethicus*), lynx (*Lynx canadensis*), red, cross, black, and arctic foxes (*Vulpes*), otter (*Lutra canadensis*), mink (*Lutreola vison*), marten (*Mustela americana*), fisher (*Mustela pennanti*), wolverine (*Gulo luscus*), wolf (*Canis occidentalis*), weasel (*Putorius*), and skunk (*Mephitis hudsonica*).

One of the most important animals in the region is the rabbit (*Lepus americanus*), for not only do the natives depend to a very large extent on it for food, but its skin also provides them with clothing and sleeping robes for winter use.

Most of the migratory game birds of economic importance in North America frequent the basin of Mackenzie river during the summer months. As soon as spring commences millions of ducks and geese of various kinds migrate northward to breed in the lakes and marshes of the region and of the coast and islands beyond. The marshes at the west end of Athabaska lake are a favourite halting place in this migration and large numbers of birds are to be found there in spring and autumn.

Spruce grouse, ruffed grouse, sharp tailed grouse, and ptarmigan remain in the region throughout the year and are found more or less abundantly throughout different parts of it.

The lakes and streams of the region abound in food fishes of various kinds. Whitefish, lake trout, pike, and sucker are found in nearly all the lakes and streams. Grayling, pickerel, and goldeye have a more limited range. Herring are found in the Mackenzie below the Liard and are abundant in Great Bear lake. The inconnu ascends Mackenzie and Slave rivers as far as the rapids at Fort Smith and is abundant in Great Slave lake the whole year round.

The only industry, apart from the agricultural one that is just being developed on the southern fringe of the basin, is that dependent on the fur-bearing animals. Virtually the whole population, except the farming communities referred to, are more or less interested in the fur trade, and the few scattered settlements that are situated at intervals of 100 to 200 miles along the main rivers were originally established, and are still maintained, for the purpose of trading furs with the natives.

The fisheries, if we neglect a small industry on Lesser Slave lake, are still undeveloped except for purely local use. They are, however, one of the most valuable assets of the region. Thousands of whitefish are caught annually in Athabaska, Great Slave, and some of the smaller lakes. In 1887, McConnell estimated a catch of 500,000 pounds of this fish in Great Slave lake, to supply three posts, and from Athabaska lake Ogilvie states that about 80,000 fish were taken in the autumn fishing to supply Fort Chipewyan alone. Great Bear lake, though containing the finest quality of fish of any of the northern lakes, is still untouched, and besides whitefish is known to be well stocked with lake trout and the Great Bear Lake herring.

#### TIMBER

The whole basin of Mackenzie river is thickly wooded (Plate VIII), with the exception of a narrow strip north of the east end of Great Slave lake, which



forms part of the Barren grounds, and some areas of prairie land in the upper Peace River region. The variety of trees, however, is not great and includes only five coniferous and three deciduous species, namely, banksian pine, tamarack, white spruce, black spruce, balsam fir, and birch, aspen, and balsam poplar. All of these, excepting the banksian pine and balsam fir, extend practically to the limits of forest growth.

Banksian pine (*Pinus banksiana*) is the only species of pine in the region. It is found on sandy or gravelly ridges throughout the whole southern portion of the basin and extends down the valley of the Mackenzie to latitude  $64^{\circ} 30'$ , almost to the mouth of Great Bear river.

Tamarack (*Larix americana*) grows throughout the whole basin northward to the limit of trees and is found mainly in the muskegs. Its wood is tougher than any other native tree and it is consequently used to some extent locally for purposes in which strength and hardness are required. It, however, does not grow in sufficient size and quantity to make it commercially important for lumbering.

White spruce (*Picea alba*) is the most important timber tree of the region and practically the only one that can be used for building or general constructive work. Its range is northward to the limit of the forest and it even extends eastward along the valleys of certain rivers into the Barren grounds. It grows to best advantage along the banks and on the islands of the streams and even as far north as latitude 61 degrees, on the Slave and Liard rivers, attains a diameter of 30 inches. Farther north along the valley of the Mackenzie it does not grow as large and there is a lesser quantity of merchantable timber, but even at the head of the delta on Peel and Mackenzie rivers it reaches a diameter of 18 inches and a height of over 100 feet. Back from the river banks the tree is always smaller and except in a few sections of the southern part of the basin, there are few bodies of commercial spruce in the interstream areas. The rocky Laurentian plateau to the east has not as a general rule the soil conditions necessary to produce spruce timber of commercial dimensions. The best groves of spruce are certainly to be found in the valleys of the Great Central plain and of the Cordilleran region.

Black spruce (*Picea mariana*) has virtually the same range as the white spruce, but is confined mainly to the muskegs where it does not grow to large size. For this reason, and also because it makes a poorer quality of lumber, it is now of little use and not likely ever to be useful, except for pulpwood.

Balsam fir (*Abies balsamea*) is found along the valleys of Athabaska and Peace rivers and in the Cordillera for a considerable distance north, but it is not as abundant as the spruces.

Balsam poplar (*Populus balsamifera*) extends over almost the whole basin, but towards the mouth of the Mackenzie becomes very small.

The aspen (*Populus tremuloides*), also, extends over the whole region and attains a large size along the valleys of the southwestern tributaries of the Mackenzie. Splendid groves occur in the valleys of Peace and Athabaska rivers, and it is one of the principal trees of the Peace River basin.

Birch (*Betula papyrifera*) is an important and widespread tree, the range of which is coextensive with the range of the aspen. It reaches its perfection in the southern part of the basin where trees 12 inches in diameter are common, but it gradually decreases in size northward. The tree is of great importance to the natives, who use its bark in the construction of canoes and baskets and its wood for toboggans, snowshoes, and handles of axes and other tools.

Considering the area of the Mackenzie basin and the fact that it is forested almost throughout, the quantity of merchantable timber is relatively small and is confined in all parts entirely to the stream valleys. The best areas are to be found on the tributaries of the Mackenzie which flow from the west, such as Athabaska, Peace, and Liard rivers. On Mackenzie river there is probably little more than is sufficient to supply the needs of the immediate vicinity and since it is a northward flowing stream its timber cannot readily be used for the settlements that are growing up in the southern part of the basin.

A great deal of valuable forest has been destroyed in past years, both through the carelessness of travellers with regard to camp fires and also through the deliberate starting of fires by the natives so as to improve the hunting. Forest fires are naturally more common along the regularly travelled routes, and in the unexplored portions of the country Indian canoe routes are often marked by the patches of burnt forest on the portage trails and at camping places.

Through the efforts of the Dominion Forestry Department, however, the waste by fire is by no means as great now, and the natives are being educated to see the folly of allowing fires to spread. This waste is all the more deplorable since in that northern region tree growth is slow and reforestation consequently takes much longer than in more southern regions.

#### TRANSPORTATION FACILITIES

During the last one hundred and thirty years the principal routes for the transportation of supplies into the basin of Mackenzie river have changed a number of times, but in changing, the old routes have not been entirely abandoned and all of them are still used occasionally.

From the time of the first entry of the fur traders within the limits of the basin, in the last quarter of the eighteenth century, up to nearly forty years ago, the main line of transportation was from the Churchill river across the height of land at Methy portage to Clearwater river. Having entered the basin of Mackenzie river at that point the routes followed the main streams of Athabaska, Slave, Peace, Mackenzie, Liard, and Bear rivers to the various trading posts situated on these streams, for all supplies were then carried in York boats propelled by crews of half-breed voyageurs or Indians. Winter travel also followed these routes.

When the main line of the Canadia Pacific railway was about completed, the route to the north country changed, and with Edmonton as a distributing point a road was opened up across the height of land north of that point to Athabaska river at Athabaska. Athabaska river then became the main line of travel, and in spite of the long series of obstructions in the rapids between Grand rapids and McMurray, all supplies were transported at considerable risk and loss down this river, in scows, as far as McMurray. At that point they were transhipped to river steamers and by these were carried and distributed to the trading posts, transhipments for the upper Peace river taking place at Vermilion chutes and for the lower Mackenzie at Smith rapids.

For the upper Peace River region west of Hudson Hope, the line of entry to the basin of Mackenzie river was from Fraser river across the divide at Giscome portage and thence down McLeod and Parsnip rivers to the main Peace.

On account of the large volume of traffic in fur-trading supplies transported by the Athabaska River route, the first railway into the basin of

Mackenzie was the Athabaska branch of the Canadian Northern railway, which was built from Edmonton to Athabaska mainly to carry these supplies. This railway, with the Athabaska river north and northwest of it, continued to be the main line of travel to the north until the year 1915, although many settlers for some years previous to that date travelled overland from Edmonton or Edson by way of trails or wagon roads that were being opened up into the farming and ranching districts of the upper Peace River region.

At present two other railway lines extend north or northwest into the basin of Mackenzie river. One of them, the Alberta and Great Waterways railway, has been built from Edmonton northward by way of lac la Biche to Clearwater river near McMurray, and will probably be continued soon to McMurray. When completed this railway will be the shortest and most direct route to the far northern interior of Canada.

The other line, the Edmonton, Dunvegan, and British Columbia railway, with its branch the Central Canada railway, runs northwestward into the agricultural districts of the upper Peace River country. The northern terminus of the Central Canada branch is at present Peace River Crossing, at which point connexion is made with the water transportation systems which control the traffic beyond. The main line of the Edmonton, Dunvegan, and British Columbia serves the agricultural country in the basin of Smoky river and will no doubt be extended farther west up the valley of Peace river.

The discovery of oil below Norman has created a heavy demand for rapid transport facilities in the spring of 1921, and the question of establishing aerial connexions with Norman is receiving very careful consideration.

Two transcontinental railways, the Grand Trunk Pacific and the Canadian Northern, run through the extreme southwestern part of the Mackenzie River basin between Edmonton and Yellowhead pass, crossing Pembina and McLeod rivers and paralleling a portion of the upper Athabaska.

During the season of navigation on Peace river, which lasts from May until the end of October, steamers make more or less regular trips from Peace River Crossing downstream to Vermilion chutes, a distance of 360 miles. Less frequent trips are made, mainly in medium and high stages of water, from Peace River Crossing upstream to Hudson Hope, a distance of about 200 miles.

At Vermilion chutes, where the Peace river has a total drop of 25 feet, steamboat navigation ends for this part of the river and a wagon road 5 miles in length has been built on the south side to transport supplies around the obstruction.

Below the chutes other river steamers make occasional trips, during May, June, and July, downstream to Athabaska lake or to Fitzgerald on Slave river. These steamers also ascend the Athabaska river to McMurray to attend to any traffic that may come either by the old Athabaska River route or the Alberta and Great Waterways railway. In connexion with these river steamers two small steamers run on Athabaska lake between Chipewyan and Fond du Lac in the interest of the fur traders who have posts at the east end of the lake, but like the steamers on the lower Peace and Athabaska rivers, no regular schedule of sailings is adhered to, as on the upper Peace.

The long series of rapids on Slave river between Fitzgerald and Fort Smith presents an obstacle to the Athabaska and Peace Rivers steamers which prevents them from continuing any farther north, and all goods have to be transhipped by wagon along a road 16 miles in length to steamers at the northern side of this obstruction.

From Fort Smith there is an unobstructed run of about 1,300 miles, to Fort McPherson at the head of the delta of the Maekenzie, by way of Slave river, Great Slave lake, and Maekenzie river, and recent soundings have shown that the steamers that make this run could continue out to the Arctic ocean nearly 200 miles farther through one of the eastern channels of the Maekenzie. The steamers of the Hudson's Bay Company, the Northern Trading Company, and Lampson and Hubbard Company make the trip to the delta of the Maekenzie once a season, but they are run on no regular schedule and solely for the convenience of these companies. The round trip is made in about four weeks. These boats each make a second trip later in the season either to Norman or Good Hope. This trip, made in August, is usually the last of the season, though navigation could be extended into September.

Accommodation is provided for passengers on all these boats, but if travellers propose getting into the country away from the main line of travel on the Maekenzie river they must make their own arrangements for transportation up the tributaries of the Maekenzie.

Besides those water routes over which steamers now run and which have a total length of river and lake shore-line of about 3,600 miles, there are, in the northern section of the basin, navigable waterways tributary to Maekenzie river which have a total length of over 3,000 miles of river and lake shore-line.

The whole system of waterways is divided naturally into four sections, each of which is separated from the adjoining one by natural obstructions or falls or heavy rapids which steamers cannot surmount. These sections are: (1) Athabaska River section; (2) Peace River section; (3) Athabaska Lake section; and (4) Maekenzie River section. These waterways are tabulated below, the distance being given in round numbers because of lack of accurate surveys:

*Navigable Waters of Mackenzie Basin*

Mackenzie River section:	
Mackenzie river, below Great Slave lake.. . . . .	1,200 miles.
Peel river, to mouth of Wind river.. . . . .	250 "
Great Bear river.. . . . .	90 "
Shore-line, Great Bear lake.. . . . .	1,360 "
Liard river.. . . . .	440 "
Shore-line, Great Slave lake.. . . . .	1,440 "
Slave river, Fort Smith to Great Slave lake.. . . . .	200 "
Total.. . . . .	4,980 "
Athabaska Lake section:	
Slave river, Athabaska lake to Fitzgerald.. . . . .	100 miles.
Peace river, Slave river to Vermillion falls.. . . . .	220 "
Shore-line, Athabaska lake.. . . . .	560 "
Athabaska river, Athabaska lake to McMurray.. . . . .	170 "
Clearwater river.. . . . .	80 "
Total.. . . . .	1,130 "
Peace River section:	
Peace river, Hudson Hope to Vermillion falls.. . . . .	550 miles.
Athabaska River section:	
Athabaska river, Grand rapids to McLeod river.. . . . .	325 miles.
Lesser Slave river and lake.. . . . .	115 "
Total.. . . . .	440 "
Total for whole Mackenzie basin.. . . . .	7,100 miles.

The Athabaska River section has a length of navigable river and lake of about 440 miles, on which steamers drawing 2 feet of water may run.

This section is separated from the Athabaska Lake section by 90 miles of rapids on Athabaska river, extending from Grand Rapids to McMurray, which are navigable with difficulty for scows and canoes.

The Peace River section is 550 miles in length and extends from Hudson Hope down to Vermilion falls, and is navigable for steamers with a 2½-foot draft. The Wabiskaw river, a tributary of the Peace, in this section is said by McConnell to be navigable for powerful river steamers for a distance of 150 miles, but is not included in the table.

This section is interrupted at its upper end by the Peace River canyon, where the river breaks through the Rocky mountains, and is separated from the Athabaska Lake section by the rapids known as Vermilion chutes, where there is a fall in the river of about 25 feet. This obstruction could possibly be overcome by locks to such an extent as to allow steamers to pass from the Peace River section into the Athabaska Lake section.

The Athabaska Lake section has 570 miles in length of navigable river, for boats of 2½-foot draft, and a shore-line on Athabaska lake of about 560 miles in length, making a total of 1,130 miles. It is separated from the Mackenzie River section by a series of rapids on Slave river about 16 miles in length, where there is a total fall of 125 feet. This break in navigation is now overcome by a wagon road of 16 miles from Fitzgerald to Fort Smith, but scows and light craft are usually taken down through the rapids by making four short portages.

The Mackenzie River section is by far the most important of the whole system, covering as it does about 4,980 miles of known river and lake shore-line, on which a minimum depth of water, ranging from 2 feet to 6 feet, may be found. This section embraces the trunk stream from Fort Smith down to the Arctic coast, a distance of 1,500 miles, over which a depth of 5 feet of water can be obtained. This, with the shore-line of Great Slave lake, 1,440 miles in length, the Liard river, and the small part of Peel river, is the only part of the section that is now being used by steamers. The remainder of the navigable waters of the section are available only for the light-draft steamers and cannot be navigated by the deep-draft steamers that now ply on the portion previously mentioned. Liard river is obstructed on its lower part by a strong rapid which, however, is ascended by a powerful light-draft steamer with the aid of a line, making the navigable water on this stream 440 miles in length. Great Bear river, 90 miles in length, also has a shallow rapid about half-way up its course, which could possibly be ascended in the same way. With this obstruction removed or overcome, the whole of Great Bear lake, with a shore-line of about 1,360 miles, becomes connected with the Mackenzie system. Peel river is navigable for shallow-draft steamers from the Mackenzie to the mouth of Wind river.

The Mackenzie has a number of other tributaries about which little or nothing is known, but which, on exploration, might prove to be navigable for certain distances. Among these are Little Buffalo river, Hay river, Willow Lake river, Hare Indian river, Arctic Red river, and some others.

#### COMMERCIAL POSSIBILITIES

The natural resources of the basin of Mackenzie river are very varied, but as yet few commercial enterprises have been undertaken with a view to developing them. The oldest of these enterprises is that associated with the traffic in furs, but agriculture is now finding a large place in the commerce of the region. Transportation systems, both by railway and steamboat lines, have

been developed to handle the products of both these industries; but, with the rapidly growing population and the large area of country capable of settlement that is still unoccupied, there is reason to believe that there will have to be soon a considerable increase in the transportation facilities of the region to meet its requirements.

In the southern part of the basin the agricultural industry offers probably the greatest possibilities, and though the value of the land for mixed farming, in the basins of Peace and Athabaska rivers, is becoming generally known, there is a large area of country north of this region, as far as latitude 61 degrees north, in which agriculture on a considerable scale could be carried on by hardy northern people. This northern portion is more difficult of settlement and the variety of crops that can be grown more limited, so that it will only be after the more southern lands are fully taken up that the northern portion will be occupied by settlers. There is, however, in this whole area of about 200,000 square miles, room for a large population which ought to be able to support itself mainly or wholly by farming, ranching, or a mixture of both.

The fur trade has been carried on continuously within the Mackenzie basin since the latter part of the eighteenth century, and is still a large factor in the industry of the region. Trading posts are scattered here and there throughout the southern half of the basin, even among the agricultural communities, but in the northern half of the basin practically the entire population is actively interested in that industry and exists by reason of its continuance. The history of the region is intimately bound up with the operations of the fur traders, and the few scattered settlements situated at intervals of 100 to 200 miles along the main streams were originally established and are still maintained for the purpose of trading furs with the natives. Three principal companies, the Hudson's Bay Company, Lampson and Hubbard Company, and the Northern Trading Company, divide among them the trade in the northern half of the basin, and in the southern half there are a number of smaller firms and individual traders. Most of the high-grade furs, such as fox, beaver, marten, mink, lynx, ermine, and otter, are obtained within the region and it is considered to be the best fur-producing portion of Canada. Of the \$5,000,000 worth of furs exported annually by Canada, the basin of Mackenzie river is said to supply nearly \$2,000,000 worth. The fur-trading field, however, is now pretty well covered by the companies represented, though there are good opportunities for the individual trapper to make a living.

In the mineral industry very little has been done except in the recovery of placer gold in those western portions of the basin which lie outside the scope of this report, namely in the gold fields of Cassiar and Omineca, and in the prospecting for oil. Some drilling has been done on Athabaska and Peace rivers, but the drilling that has met with most promising results is that on the Mackenzie 45 miles below Norman. Here a flow of oil was struck in 1920. The strength of the flow is encouraging and a remarkable interest is being shown in the possibilities of the district. The Devonian formation in which the oil occurs is very widely distributed through the Mackenzie basin and the discovery of oil will probably lead to much prospecting and further boring operations. Prospecting for metallic minerals has been carried on to a very limited extent in the southeastern portion of the basin, and in the southwestern portion, good results have been obtained in the case of coal, and some coal fields have been located.

To appreciate the possibilities, however, from a mining point of view, it is necessary to look at the geological map. Precambrian rocks occupy the eastern portion of the basin and deposits of iron, copper, nickel, and gold are recorded in them in certain localities. The mountainous western section is made up mainly of sedimentary rocks and with the exception of the extreme western part has not the possibilities in metallic minerals of the Precambrian area. Coal, however, occurs at a number of points and salt and gypsum at others, and placer gold is reported in some of the streams. In the Great Central plain the non-metallic minerals, coal, salt, gypsum, oil, and gas, are known to occur, as well as the metallic minerals, lead and zinc. Of these, the evidence seems to show that coal, oil, and gas will probably be the most important. Attempts to determine the value of any of these mineral occurrences mentioned have not been extensive and nearly all that is known is the brief reference in the reports of explorers or travellers.

To the prospector, therefore, first of all, and later the mining man, the basin of Mackenzie river affords a vast field of unknown but certainly great possibilities. Not only is the greater part of the basin quite unprospected, but more than one-third of it is still unexplored, and even its geographical features are unknown. What these unprospected and unexplored regions contain in mineral resources it is impossible to say and unwise to conjecture, in view of the developments that have already taken place in opening up other parts of northern Canada.

The food fishes of the streams and great lakes of the Mackenzie basin are another asset that will be utilized when methods of transportation are improved. At present the fisheries of lac la Biche and Lesser Slave lake are the only ones that have been developed to meet more than the local demands. Whitefish from these lakes are now shipped to points throughout western Canada because of the railway lines to these lakes. The more northern lakes, however, Athabaska, Great Slave, and Great Bear, contain an abundance of excellent whitefish, trout, and other food fishes, which are as yet not utilized except by the Indians and the few white people who reside on the shores of these lakes. A fishing industry of some magnitude will no doubt be developed on these lakes and at a number of other points, as soon as facilities for transportation are afforded whereby the fish can be sold in the markets of the rest of Canada, for the cold waters of these northern lakes give a firmness and flavour to the fish which can not be excelled by the fish of more southern lakes.

Lumbering is not an industry in the Mackenzie basin that can assume such proportions as in eastern Canada or on the Pacific coast. The most important tree in the district is the spruce, which grows to a fairly good size in many of the valleys, particularly those of Athabaska, Peace, and Liard rivers near the mountains. Though no doubt there will be a good local demand for lumber in the agricultural districts in the southwestern portion of the region, it will be difficult to take full advantage of the timber resources, partly because most of the streams flow northward away from the advancing settlement and partly because of the situation of the region in the interior of the continent. The commercial possibilities in lumbering, however, are to be considered.

Waterpower will no doubt be important in the commercial development of the region because of the scarcity of coal. As in the Laurentian Plateau regions elsewhere, the rivers of the eastern part of the Mackenzie basin contain a number of falls at which power could be developed. Among those which have

been noted by explorers are Black river at the east end of Athabaska lake, and Taltson, Lockhart, and Yellowknife rivers flowing into Great Slave lake.

Waterpower could also be developed on Peace river at the chutes, where there is a total fall of 25 feet, part of it being a direct drop of 15 feet, and on Slave river near Fort Smith where the river falls 125 feet in a series of strong rapids spread over a distance of about 14 miles. The most evident waterpowers and those which no doubt could be most cheaply developed occur on a number of rivers which fall over the face of the Devonian escarpment south of Great Slave lake. Little Buffalo river, for example, has a total fall over the escarpment of about 100 feet, half of which is a direct drop. Hay river also falls over the escarpment in two leaps with a total drop of 151 feet, the upper fall having a sheer drop of 105 feet and the lower one 46 feet. Beaver river, which flows into the Mackenzie immediately below the outlet of Great Slave lake, plunges in a direct fall over the same escarpment, and the two next streams north, Yellowknife river and Trout river, are also said to fall in the same way over the same escarpment. Waterpower could be developed on a number of other streams, but a sufficient number have been mentioned to show that there is much available waterpower to meet the requirements of any mining, lumbering, or other industries that may spring up in the region.

#### INHABITANTS

The white people of the Mackenzie basin are few in number and north of Peace river and Athabaska lake consist chiefly of the families of the fur traders and the missionaries of the Protestant and Roman Catholic churches. These reside at the small posts (Plate IX A and B) which are scattered at intervals of 100 to 200 miles along the valleys of Slave, Liard, and Mackenzie rivers, and their total number is very small. A considerable number of white settlers, however, have within the last five years entered the southwestern part of the Mackenzie basin and taken up homesteads in the upper part of Athabaska River basin, the basin of Smoky river, and other neighbouring parts of Peace river. The building of several lines of railway into these regions has been the cause of this large influx of people.

The natives of the region include Esquimo, and Indians of three different stocks, Athapascan, Cree, and a few Iroquois.

The Esquimo are confined to a belt along the Arctic coast, but the numbers that live or trade at posts within the Mackenzie basin cannot be much more than 150.

The Iroquois consist of a few families living about the headwaters of Smoky and Athabaska rivers, descendants of boatmen and voyageurs of the fur traders.

Crees occupy the greater part of the basin of Athabaska river and the region between that stream and the Peace.

The remainder of the Mackenzie basin is occupied by various tribes of the Athapascan family, comprising in that region about 6,000 to 7,000 individuals. These tribes are situated as follows: Chipewyans in the regions south and east of Athabaska lake, Caribou-eaters north of Athabaska lake, Yellowknives east of Great Slave lake, Dogribs north of Great Slave lake, Hares north of Great Bear lake, Beavers in the upper part of Peace river and Fort Nelson river, Slavis in the valley of the Mackenzie from Great Slave lake to Great Bear river, Loucheux in the basin of Peel river, and Sikannis, Kaskas, Nahannis, and other



mountain tribes in the Rocky and Mackenzie mountains. These and the other native tribes live by hunting and trapping and very much in the same manner as they did before the advent of the white people. They have, however, all become christianized and are adherents either of the Church of England or the Roman Catholic church.

## GENERAL GEOLOGY

### SUMMARY

The Mackenzie basin is underlain in part by rocks of Precambrian age, forming the western edge of the great Canadian Shield, but to a much greater extent by sediments of later deposition. The sediments have suffered very little deformation and, except in the mountains on the western edge of the basin, display only a few minor elevations.

The Precambrian rocks lie east of a line following Slave river and the north arm of Great Slave lake and extending northwest to Great Bear lake. The greater part of the Precambrian area is underlain by granites and gneisses. Small areas of older, highly metamorphosed rocks are found, such as quartzite, slate, and sericite and chlorite schists; there are also later sandstones that have been intruded by basic igneous rocks. The wide stretches of granite and gneiss offer little attraction to the prospector, but the older, much altered rocks and the later basic dykes, sills, and flows may carry metallic minerals in commercial quantities.

The sediments lying to the west of the Precambrian area consist of dolomites, limestones, and shales of Silurian and Devonian age, and sandstones and shales of Cretaceous and Tertiary age. A great unconformity marks the contact between the Precambrian and Palæozoic formations. Although unconformable relations exist between the Silurian and Devonian rocks, the Devonian and Cretaceous, and the Cretaceous and Tertiary in the north, there is no marked discordance of dip except probably between the Tertiary series and the underlying rocks.

The Devonian limestones and shales which are frequently bordered on the east by a narrow band of Silurian dolomites and gypsum-bearing beds form a broad belt stretching from lake Athabaska northward nearly to the Arctic coast. They are concealed to the south and southwest by Cretaceous rocks, and towards the delta of the Mackenzie also pass beneath Cretaceous sediments. These later sediments also overlie the Devonian rocks in long stretches along the Mackenzie above and below Great Bear river and are exposed to the west and north of Great Bear lake. The Devonian rocks are in general nearly horizontal east of the Rocky Mountain front, but within the Rocky Mountain system which the Mackenzie reaches at about 90 miles below Simpson, sharp anticlinal and synclinal structures prevail.

The Cretaceous sediments resting upon the Devonian rocks at the south occupy nearly the whole of the valleys of Athabaska and Peace rivers and probably extend in a northwest direction to Liard river; to the south they stretch beyond the area dealt with in this report through Alberta and Saskatchewan into the United States. They consist of a series of sandstones and shales, and are nearly horizontal in attitude, but dip slightly to the south or southwest in the basins of Athabaska and Peace rivers.

A few small areas of Tertiary sandstones and clays are known. The Paskapoo formation is exposed on Pembina river, a tributary of the Athabaska. There is a small area of Tertiary sediments on the Mackenzie at the mouth of Great Bear river and another on Peel river. These sediments are gently undulating, but do not depart much from the horizontal attitude.

As settlement advances northward and transportation lines are constructed, increased attention is directed to the possible economic mineral deposits of the Mackenzie basin.

Coal seams of workable thickness are found in the Cretaceous sediments and some of these are being mined in the basin of the Athabaska. Lignite seams also occur in the Tertiary beds of Mackenzie and Peel rivers, but these are too remote from a market to be of any importance for many years to come.

Extensive deposits of bituminous sands are exposed on Athabaska river at the base of the Cretaceous system and investigations have been made into their possibilities for commercial application.

A gas-bearing horizon in the Cretaceous, on the Athabaska, was discovered by the Geological Survey in 1897. Petroleum has been found on the Mackenzie below Norman and in borings on Peace river. Very little of the country, however, has yet been prospected.

Extensive gypsum deposits are found on Peace river in a position favourable for quarrying and for transportation. Gypsum is also found on Slave river, in the escarpment west of Slave river, and elsewhere.

Salt beds have been reported as discovered in bore-holes at McMurray. Brine springs west of Fort Smith have furnished that part of the Mackenzie valley with its salt supply for many decades.

Some clays of good grade are found on the Athabaska.

TABLE OF FORMATIONS

Quaternary.....	Pleistocene and Recent.....	Till, stratified sand, and gravel.
Tertiary.....	Paskapoo..... Not subdivided.....	Sandstone. Sandstone and shale.
Mesozoic.....	Cretaceous.....	Peace and Smoky Rivers. { Wapiti..... Sandstone. { Smoky River..... Shale. { Dunvegan..... Sandstone. { Fort St. John..... Shale. { Peace River..... Sandstone. { Loon River..... Shale. { Edmonton..... Sandstone. { La Biche..... Shale. { Pelican sandstone.. Athabaska River. { Clearwater..... Shale. { Grand Rapids..... Sandstone. { McMurray..... Sandstone, bituminous. Not subdivided..... Sandstone and shale.
	Triassic.....	Arenaceous limestone and calcareous sandstone.

TABLE OF FORMATIONS—*Concluded.**Unconformity.*

Palæozoic.....	Upper Devonian.....	Shales and limestones. Limestones with some shales.
	Middle Devonian.....	
	<i>Unconformity.</i>	
	Silurian.....	Dolomites and shales with gypsum.

*Unconformity.*

Precambrian.....	Late Precambrian.....	Sandstone, limestone, and basic flows and intrusives.
	<i>Unconformity.</i>	
	Granites and gneisses.....	
	<i>Intrusive Contact.</i>	
	Early Precambrian.....	Schists, slates, limestones, and quartzites.

## DESCRIPTION OF FORMATIONS

*Precambrian*

The distribution of the Precambrian rocks of the Mackenzie basin coincides with the physiographic province known as the Laurentian plateau, which occupies a strip along the eastern border of the basin about 800 miles in length and ranging from 80 to 280 miles in width. On the east, the Precambrian rocks extend far beyond the boundaries of the region over to Hudson bay, but on the west they pass under a cover of later stratified rocks. The contact with these younger rocks runs from Methy portage to the west end of Athabaska lake, thence down the valley of Slave river to Great Slave lake, and from the north arm of that lake north-northwesterly to McTavish bay on Great Bear lake. North of Great Bear lake the contact has not been defined, but it probably soon passes northward outside the watershed of Mackenzie river, reaching the Arctic coast at Darnley bay.

The Precambrian rocks of this region have not been subdivided in such great detail as they have been in the Lake Superior region or in northern Ontario, and only three different subdivisions have been recognized and mapped. More detailed work will no doubt show the same complexity of formations as exists in other regions where the Precambrian has been more carefully studied.

The oldest of the three groups of rocks into which the Precambrian has been subdivided consists of highly metamorphosed schists, slates, limestones, quartzites, and volcanic rocks, occurring in isolated areas as erosion remnants. This group includes formations that have been uncertainly correlated with the Keewatin, Huronian, or Grenville of other regions.

These rocks have been intruded by granites or gneisses of probably more than one age.

Overlying these two groups is a series of younger rocks, not greatly disturbed, consisting of sandstones, conglomerates, shales, limestones, and some associated volcanic rocks that have been referred to as Keweenaw or Animikie.

*Early Precambrian.* Rocks that have been more or less doubtfully correlated with the Keewatin or Huronian and which consist mainly of schists, slates, limestones, and quartzites occur here and there throughout the Precambrian of the Mackenzie basin in areas usually small but sometimes many square miles in extent. The characteristic feature of the rocks of all the areas is that they are intruded by the granites or gneisses of the succeeding division, though they probably represent formations of vastly different ages. They occur in isolated bands which are merely remnants of formerly more widespread series of rocks that at one time probably covered the greater part of the whole region. They have, however, been so reduced in area by intrusions of granites and by deep erosion that they now form apparently the smallest portion of the Precambrian of this region.

Three main bands of these rocks on the north shore of Athabaska lake are described by Tyrrell<sup>1</sup> under the name Huronian, and in a later report are referred to by Alcock<sup>2</sup> as portions of the Tazin series.

The largest of these bands is situated on Beaverlodge bay "where it is developed for 16 miles along the shore and extends back at least 10 miles to the north. It consists of limestone, quartzite, slate, and sandstone. The limestone is bluish in colour, weathering to a rusty brown, and occurs only in local patches cut by gneiss. The quartzite is much the most abundant type in the series. It is white and in places reddish, is very badly brecciated, and in several localities contains considerable hematite."<sup>3</sup> The second band, which occurs on Slate island and the adjacent mainland, consists of dark grey and brown schists, quartzite, and breccia. The third band occurs near Sand point and runs parallel to the shore. It consists of beds of quartzite and schist which form cliffs along the lake shore for about 2 miles.

In the country north of Athabaska lake, rocks of the Tazin series are described by Camsell<sup>4</sup> as occurring in seven distinct areas along the Tazin and Taltson rivers. These areas are situated along the canoe route which follows these two streams and are designated as follows: Thluicho Lake area, Thainka Lake area, Long Reach area, Hill Island Lake area, Thekulthili Lake area, Kozo Lake area, and Tsu Lake area. They occur in elongated bands from 6 to 28 miles in length. The rocks strike north or northwest, and consist of schists, quartzites, argillites, limestones, and some volcanic rocks, all dipping at high angles. All these rocks are intruded and completely surrounded by granite or gneiss and have been highly metamorphosed thereby. They generally occupy depressions that form the water-courses. The band on Hill Island lake, which is at least 18 miles in length, is from an economic point of view probably the most important in this region. It consists of narrow, interbedded bands of limestone, argillite, and mica schist, which stand vertically and strike north and south. Numerous veins of quartz mineralized by pyrite cut the beds; veins of the inter-

<sup>1</sup> Geol. Surv., Can., Ann. Rept., vol. VIII, p. 17 D.

<sup>2</sup> Geol. Surv., Can., Sum. Rept., 1914, p. 61.

<sup>3</sup> Alcock, F. J., op. cit.

<sup>4</sup> Geol. Surv., Can., Mem. 84, p. 25.

bedded type are also found. Another band on Thekulthili lake also traversed by quartz veins contains a bed of conglomerate which carries pebbles of an older granite.

On Great Slave lake, rocks consisting mostly of schists which have been classed as Huronian by Robert Bell<sup>1</sup> occur "around Yellowknife bay and thence to Gros Cap, including some islands in this part of the lake, also on islands in the vicinity of Fort Rae and again at the head of lake Marian.....Rocks which may belong to this series were observed on the southeast side, to the north-eastward of the mouth of Slave river."

Though all these bands are areally of no great extent, they are much the most important economically of all the divisions of the Precambrian, and, although no commercial mineral deposits have as yet been found in this division within the limits of the Mackenzie basin, the rocks of which they consist have been proved in other parts of Canada and in the United States to contain valuable deposits of gold, silver, and iron ores. The rocks are frequently traversed by quartz veins which in the band on Yellowknife river are known to carry free gold. It is advisable, therefore, for the prospector working in the Precambrian of this region to pay particular attention to these rocks, as they are more likely than any other formation to contain deposits of metallic ores.

*Granites and Gneisses.* Granites and gneisses cover the greater part of the Precambrian of the Mackenzie basin. Along the canoe route followed by Camsell between Athabaska and Great Slave lakes by way of the Tazin and Taltson rivers, granites and gneisses "occupy about 86 per cent of the region immediately adjacent to the line of traverse, and it is very likely that they cover by far the greater part of the whole Taltson River basin, because most of the glacial boulders scattered over the surface of the region are of these rocks."<sup>2</sup> Although this proportion may not hold over the whole of the Precambrian it is cited as evidence of the great areal extent of the granites and gneisses relative to the other rocks of this age.

On Athabaska lake Tyrrell<sup>3</sup> describes the rocks of this group as consisting of hornblende granites, biotite granites, muscovite granites, and granitoid gneisses with gabbros and norites. They are all closely associated with each other and although several ages are represented they are all classed together in default of evidence whereby they could be arranged in a definite time series.

The outcrops are here, as elsewhere, worn into rounded hills and ridges. The gneiss does not appear to have a persistent strike, though Alcock notes a tendency to a northeasterly trend. Under the microscope it exhibits a cataclastic structure indicating subjection at some time to severe pressure.

North of Athabaska lake, in the basin of Taltson river, the same types of rocks prevail with the addition of some diorites. In this region Camsell<sup>4</sup> notes a trend of the foliation of the gneiss ranging from north to northwest, coinciding with the trends of the bands of stratified rocks into which the gneiss is intruded. The trend here is referred to as a Cordilleran one rather than one conforming to the trend of Precambrian rocks in eastern Canada.

In the Great Slave Lake region and northward to Great Bear lake, granites and gneisses constitute a very large proportion of the bedrock. Porphyries.

<sup>1</sup> Geol. Surv., Can., Ann. Rept., vol. XII, p. 106 A.

<sup>2</sup> Camsell, C., Geol. Surv., Can., Mem. 84, p. 33.

<sup>3</sup> Tyrrell, J. B., Geol. Surv., Can., Ann. Rept., vol. VIII, p. 16 D

<sup>4</sup> Camsell, C., Geol. Surv., Can., Mem. 84, p. 33.

syenites, and granites are described by J. M. Bell<sup>1</sup> as occurring all the way from Great Bear lake to Great Slave lake, and on the east arm of Great Slave lake "granites and gneisses rise as a sea of half rounded hummocks to a general height of nearly 1,000 feet all along the northwest side of this part of the lake and also around the northeastern extremity."<sup>2</sup>

Associated with the granites and gneisses, but possibly of a later period of intrusion, are bodies of gabbro and norite occurring notably on the north shore of Athabaska lake and the country to the north.

This whole group of rocks belongs not to one period of intrusion alone, but represents different intrusions. In the main, however, the rocks cut the series of stratified rocks locally known as the Tazin series and others that have been referred to as Keewatin or Huronian. They are not in themselves mineralized to the extent of forming workable ore-bodies, but they are in places believed to have produced mineralization in the rocks into which they have been intruded.

*Late Precambrian.* The youngest Precambrian formations of this part of Canada consist chiefly of sandstones associated with basic intrusions and flows. These rocks are of wide distribution; they lie to the northeast of Great Bear lake, at the east end of Great Slave lake, and north and south of lake Athabaska; they also cover large areas lying to the east of the Mackenzie basin.

In the Lake Athabaska district the rocks consist chiefly of reddish, moderately coarse-grained sandstones, becoming in places fine-grained, thin-bedded, and shaly, and in places passing downward into conglomerate. These constitute what have been designated the Athabaska series.

<sup>3</sup>"The total area underlain by this sandstone formation is very large, extending from Cree lake on the south to Athabaska lake on the north, and from Wollaston lake on the east, doubtless to the vicinity of the valley of Athabaska river on the west, and perhaps much farther under the covering of later rocks. Cree lake lies largely within the area underlain by these rocks, and Athabaska lake seems to lie entirely within it, for the red sandstones compose many of the islands and more prominent points of its northern shore."

North of Beaverlodge bay on the north shore of lake Athabaska, thick-bedded sandstones, arkoses, and conglomerates of the Athabaska series are found, and interbedded with these is a number of flows of vesicular and amygdaloidal basalt. The series is also intruded by sills and dykes of diabase. The strata here form an open syncline and have a maximum dip of 40 degrees. There is a thickness of about 8,800 feet.<sup>4</sup> Conglomerate and shaly sandstone exposed at the northeast end of Tazin lake possibly belong<sup>1</sup> to the same series.<sup>5</sup>

Concerning the formation as exposed on Great Slave lake, Robert Bell says:

<sup>6</sup>"The northeastern continuation of the main lake-basin is excavated out of the older Cambrian or Animikie rocks resting in a long physical depression or trough in the Archæan foundation. These strata have a thickness of over 1,000 feet and they are thrown into gentle anticlines and synclines, parallel to the axis of the general trough, in which they lie. They have been deeply eroded along the anticlinal folds and the waters now filling the depressions form the

<sup>1</sup> Geol. Surv., Can., Ann. Rept., vol. XIII, p. 101 A.

<sup>2</sup> Bell, Robt., Geol. Surv., Can., Ann. Rept., vol. XII, p. 106 A.

<sup>3</sup> Tyrrell, J. B., Geol. Surv., Can., Ann. Rept., vol. VIII, p. 18 D.

<sup>4</sup> Alcock, F. J., Geol. Surv., Can., Sum. Rept., 1916.

<sup>5</sup> Camsell, C., Geol. Surv., Can., Mem., 84, p. 36.

<sup>6</sup> Geol. Surv., Can., Ann. Rept., vol. XII, p. 106 A.

various long and nearly parallel bays into which this portion of the lake is divided. These rocks consist partly of unaltered limestones varying in colour from very light- to dark-grey, drab, and red, sometimes passing into shales, and partly of sandstones, mostly red, coarse conglomerates, and red shales, together with thick sheets or overflows of greenstone, generally capping the other strata and presenting long cliffs made up of perpendicular columns or "palisades" overlooking the different bays. We could not ascertain whether all these greenstone cappings belonged to a single extensive overflow or not. Large exposures of greenstone also occur near the level of the lake, which may not form part of any general overflow. A few wide greenstone dykes were seen cutting the nearly horizontal Animikie strata beneath the crowning overflow."

In the narrows, southeast of Big Caribou island and on the tongue of land separating McLeod bay from the east bay, there are exposures of "massive light-grey, blue, or dove-coloured limestones which weather to various shades of yellow and brown, hard reddish sandstones or quartzites and fine conglomerates, and red and grey 'lumpy' jasper or chert rock. At the east bay, black shale occurs in the vicinity of the massive limestone."

Sedimentary rocks of various kinds, associated with basic igneous intrusives, are exposed at the eastern end of Great Bear lake and extend eastward beyond Coppermine river and northward to the Arctic ocean.

At Limestone point, on the north shore of Dease bay, 30 miles west of Fort Confidence, there is an exposure of "purplish dolomite which changes to a ferruginous slate. Above this comes grey, semi-crystalline dolomite, associated with light-grey quartzite." Limestones and slates are exposed at points along the shore to the east of this. Exposures of limestone, quartzite, sandstone, and basic igneous rocks occur on the rough, rocky south shore of Dease bay as far west as Narrakazoe islands. On these islands greenstone is exposed. West of this the south shore of Dease bay is low, as is also the north shore of McTavish bay for 50 miles east of cape McDonnell. Farther east the shore of McTavish bay is rocky, and greenstone intrusions are found cutting horizontal sediments.<sup>1</sup> "The eastern part of McTavish bay is composed of a series of basic rocks, or greenstones, that seem to overlie the Laurentian granites, of which, however, exposures are seen at several places. The southern part of McTavish bay and the islands there, are mostly of granite, though greenstone dykes are common." On Dease river bright red quartzite, and drab and red magnesian limestones occur, and at its mouth exposures of diabase and diorite are seen.

On Coppermine river, which lies east of Great Bear lake outside the basin of the Mackenzie, a number of basaltic flows, the upper parts of which are amygdaloidal, are found interbedded with conglomerate, sandstone, and shale. These rocks are of wide distribution, being found on Coppermine river, on the coast and islands to the north, and on Bathurst inlet. Their chief interest lies in the fact that they carry native copper.<sup>2</sup>

#### *Palæozoic (not subdivided)*

The Mackenzie basin includes extensive areas in which the sedimentary series has not been sufficiently studied to differentiate the subdivisions of the palæozoic rocks. This is true of most of the region between Great Bear and

<sup>1</sup> Bell, J. M., Geol. Surv., Can., Ann. Rept., vol. XII, p. 26 C.

<sup>2</sup> Douglas, James, "The copper-bearing traps of the Coppermine river," Can. Min. Inst., Trans., vol. XVI, pp. 83-101.

O'Neill, J. J., Geol. Surv., Can., Sum. Rept., 1916.

Great Slave lakes and of the western part of the basin. The rocks in these areas doubtless consist mainly of Silurian and Devonian sediments but Cambrian and Ordovician horizons are known to exist in the mountains at the west.

### *Silurian*

Rocks of Silurian age form the base of the Palæozoic section over a considerable portion of the eastern part of the Mackenzie River basin. They consist of dolomitic and non-dolomitic limestones, the former generally predominating; beds of gypsum and anhydrite are conspicuous elements of many of the sections.

The formation is exposed in Bear mountain near Norman and in mount Charles on Great Bear river. At the latter point the Silurian formations have a thickness of not less than 3,000 feet. The discovery by E. M. Kindle of *Halysites catenulatus* and other well-known Silurian corals, together with a brachiopod fauna which includes *Conchidium* sp., leaves no doubt of the Silurian age of the Mount Charles section. A Silurian fauna was also found in the eastern front of Franklin mountains 150 miles south of mount Charles. On the west side of the Mackenzie near the mouth of North Nahanni river 1,500 feet or more of dark dolomitic limestones which have furnished only a few poorly preserved fossils are referred to the Silurian.

Sediments carrying *Receptaculites* and several species of Silurian brachiopods and cephalopods are exposed on the west side of the north arm of Great Slave lake. These form an escarpment which probably continues northward towards Great Bear lake. According to G. S. Hume the rocks consist of a grey dolomite overlain by beds of red arenaceous limestone and gypsum.

Limestone, gypsum, and anhydrite of Silurian age are exposed in cliffs along Peace river between Peace point and the mouth of Jackfish river. They are overlain unconformably by beds of upper Devonian age. A fossil closely allied to *Spirifer corralensis* has been found in limestone outcropping on the trail to Salt river at a point 2 miles west of Fitzgerald. This limestone and the gypsumiferous dolomite exposed along Salt river near Salt Springs west of Fort Smith are thought to represent a late horizon of the Silurian. Sediments of Silurian age are also exposed on Caribou island in Slave river, and the only two outcrops of the Palæozoic known on the lower Slave have furnished fossils that appear to correlate them with late Silurian.

### *Devonian*<sup>1</sup>

The Devonian system as it is developed in the Mackenzie basin includes a large variety of rocks which refined studies will divide into a number of lithologic units. For the purpose of a report having the broad scope of the present one it appears best to group the various formations which in the Great Slave Lake district have received separate names<sup>2</sup> and the terranes of the northern part of the basin into two subdivisions. Shales predominate in the uppermost of these divisions and limestones in the lower one. The fossils show these two divisions to belong respectively to the upper and middle Devonian and these terms will be used in referring to them.

An unconformity marks the base of the Devonian, and both the rocks on which it rests and the basal beds of the Devonian system vary widely in age in different parts of the Mackenzie basin. In the eastern part of the Clearwater

<sup>1</sup>The description of the Devonian formations is contributed by E. M. Kindle.

<sup>2</sup>Cameron, A. E., Geol. Surv., Can., Sum. Rept., 1917, pt. C, p. 25.



River section the middle Devonian limestones appear to rest directly on the Precambrian rocks. A great thickness of Silurian rocks separates the Devonian from the Precambrian beds in the northern part of the basin. On Peace river the middle Devonian limestones are absent—an early upper Devonian horizon follows a Silurian series.

The unconformity at the top of the Devonian results in a similar divergence in the age of the uppermost beds of the Devonian section. At the Ramparts on the lower Mackenzie the Cretaceous rests on middle Devonian limestone. On Hay river and generally in the southern part of the basin, the upper Devonian and Cretaceous are in contact.

*Middle Devonian.* A thick series of limestones with which some shale beds are associated represent the lower division of the Devonian. These beds are well exposed and their relations to one of the associated shales are clearly shown in the Ramparts section where the beds are essentially horizontal and form cliffs about 200 feet in height. Approximately 250 feet of heavy-bedded limestone and 95 feet of underlying drab shale are exposed in this gorge. The whole of the upper Devonian series is missing from the Ramparts section, and apparently some of the middle Devonian, the Cretaceous shale resting directly on the middle Devonian limestone at the southern end of the gorge. *Stringocephalus burtoni* and other fossils show the identity of a portion of the limestone at the Ramparts with the Presquile dolomite on Great Slave lake. On Great Slave lake the lower Devonian limestones have been divided into three formations as follows:

- Slave Point limestone.
- Presquile dolomite.
- Pine Point limestone.

These formations in the Great Slave Lake section are described as follows by Cameron<sup>1</sup>:

“The Pine Point limestones, the lowest member of the series, are exposed in the vicinity of Resolution, at Pine point on the south shore of the lake, and on Ketsicta point on the north shore. They are thin-bedded, bituminous, dark-coloured, fine-grained limestones and limy shales.

“The thickness of the Pine Point series is not directly observable, but from structural evidence appears to be about 100 feet.

“The Presquile dolomites, overlying the Pine Point series, are exposed at Presquile point and on Burnt islands east of Pine point on the south shore. On the north shore they show as the oil-bearing dolomites at the tar springs on Nintsi (Windy) point and on the shores of Sulphur bay. Although not exposed elsewhere on the north shore of the lake, structural conditions suggest their presence in the region between Tagkatea and Ketsicta points.

“Exposures show this formation to consist of two members: an upper, thin-bedded, dolomitic limestone highly fossiliferous and carrying the diagnostic fossil *Stringocephalus burtoni*, and a lower member composed of a coarsely crystalline porous and cavernous dolomite. This latter is the oil-bearing horizon at the tar springs on Nintsi point. The formation is estimated to have a thickness of about 200 feet.

“The Slave Point limestones, composing the upper formation of the middle Devonian, are exposed on the south shore, from Presquile point to High point,

<sup>1</sup> Cameron, A. E., Geol. Surv., Can., Sum. Rept., 1917, pt. C, p. 26.  
15850—5½

ou Buffalo river, and on the north shore at Slave point and along the lake shore between House and Moraine points.

\* "This formation is composed of thin-bedded, medium-grained, dark grey, and slightly bituminous limestones and has an estimated thickness of about 160 feet."

The middle Devonian limestone series is represented by a dolomitic limestone in the upper part of the Clearwater section and by an outcrop of limestone at the mouth of Mikkwa river below the chutes on the Peace. Another horizon of this series outcrops opposite La Butte on Slave river.

The finest exposures of the middle Devonian limestones occur, however, in the mountains which for 300 miles border one or both sides of Mackenzie river between the mouth of North Nahanni and Carcajou rivers. These beds form the sides of the three sharply folded anticlinal mountain ridges which trend east and west in the vicinity of the mouth of Carcajou river. The higher slopes of the Bear Mountain range, which extends along the eastern side of the Mackenzie from the mouth of Great Bear river to the vicinity of Carcajou mountain, consist of middle Devonian limestone, which dipping towards the southwest, passes successively under the upper Devonian and Cretaceous shales. These southwesterly dipping limestones and the beds which follow them, together with the rocks in the first range of the Mackenzie mountains southwest of Carcajou river, may be found to form the sides of a great synclinal trough some 30 miles in width. In Bear mountain the middle Devonian limestones reach the river bank about 3 miles below Norman. Most of the southern end of this mountain consists of Silurian sediments.

South of Norman for some 60 miles the middle Devonian limestones form the slopes of mountains which are generally separated from the Mackenzie by a plain floored with Cretaceous shales several miles in width. In Rock-by-the-river-side opposite Wrigley the middle Devonian limestones again appear in the bank of the Mackenzie. The western slopes of this mountain, Rocky island immediately above Wrigley, and the adjacent eastern bank of the river consist of middle Devonian limestones dipping at high angles. The end of the mountain, which faces the river, shows a closely folded antiline, the northwest side of which consists of Devonian limestones dipping at an angle of about 75 degrees. The core of this antiline is a magnesian limestone which is believed to be of Silurian age.

The western slopes of the mountain range which lies about 18 miles east of Wrigley and extends south to Willow Lake river, consist in large part of middle Devonian limestones. Silurian beds are known to form the top and eastern face of this range east of Wrigley. The long east-facing scarp which extends northward from North Nahanni river near the Great Bend of the Mackenzie is capped by middle Devonian limestone. The 2,000 feet or more of nearly barren magnesian limestone below it appear to be of Silurian age. The Devonian limestone on the summit of Lone mountain on the south side of the Nahanni at the Great Bend has a thickness of about 220 feet. This limestone also caps the great scarp which touches Liard river at the mouth of South Nahanni river.

The most northerly known occurrence of these limestones in the Mackenzie basin is in a cliff exceeding 100 feet in height on Gull lake east of the Mackenzie delta.<sup>1</sup> Gull lake is probably Campbell lake, or one of the small lakes near it between the delta and the most southerly of the Eskimo lakes.

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<sup>1</sup> Kindle, E. M., *Am. Jour. Sc.*, vol. 42, p. 246, 1916.

*Upper Devonian.* The lower Devonian formations are followed by a series in which shales predominate over limestones. In the vicinity of Norman a fissile black shale immediately follows the middle Devonian limestone series and rests unconformably on it. These beds outcrop on and near the Mackenzie just north of Bear mountain.

These beds if present in the Great Slave Lake basin have not been observed. In the Slave Lake section greenish shales are the lowest beds known which follow the lower Devonian.

On the eastern bank of Mackenzie river, opposite Simpson, greenish-grey clay shale outcrops in horizontal beds exposing a thickness of about 140 feet. This shale is without limestone bands and is almost or quite free from sandstone bands. It weathers to small flakes of fissile shale. Excellent exposures of this shale occur on both sides of the Mackenzie about 20 miles above Simpson. Along this part of the river the banks expose sections from 50 to 150 feet thick. Fossils are very rare except in certain narrow bands of the shale which were located only after considerable searching. Because of the excellent exposures of this shale near Simpson, it has been called the Simpson shale. Neither the top nor the bottom of this formation has been observed, but the beds which immediately follow are well exposed in the Hay River section on the south side of Great Slave lake and carry the *Spirifer disjunctus* fauna. The latest beds preceding it which have been observed in the Great Slave Lake section are those outcropping on the south shore at Sulphur point.

A small outcrop of the Simpson shale occurs on the west bank of the Mackenzie under the glacial till about 12 miles below Simpson and  $2\frac{3}{4}$  miles below Marten river. Good exposures of these beds outcrop 5 miles above Rabbitskin river on the east bank of Mackenzie river.

The most northerly locality at which the Portage fauna was found is about 150 miles below Simpson on the east bank of Mackenzie river. At this locality, which is 11 miles below old Fort Wrigley and opposite the lowest of four islands, 40 or 50 feet of dark, lead grey, rather soft shales outcrop.

*Buchiola retirostriata* is an abundant species in the fauna found in the Simpson shale and it differs in no way from the characteristic and widely distributed *B. retirostriata* of the New York Portage.

The shale series just described is followed by shales in which limestones become a conspicuous element a short distance above the base. A fauna in which *Spirifer disjunctus* is conspicuous characterizes the highest beds of the Devonian.

Alexandra falls of Hay river show the best section of the upper division of the upper Devonian which is known. Mr. A. E. Cameron has measured the following section at this locality.

	Feet.
Massive, arenaceous limestone. . . . .	30
Thick and thin-bedded limestone, shaly bands with fossils, very fine-grained, grey. . . . .	62
Coraliferous limestone, bituminous. . . . .	16
Red-brown, medium-grained limestone. . . . .	12
Blue-grey shale. . . . .	5
Reddish sandstone, ripple-marked. . . . .	7
Blue-grey, soft shales. . . . .	47
Massive, red-brown limestone. . . . .	8
Shaly limestone, many fossils. . . . .	12
Thin-bedded, brown limestone. . . . .	21
Blue-green, clay shales, limestone layers with many fossils. . . . .	42
Highly fossiliferous limestone. . . . .	20
Blue-green clay shale. . . . .	15
Flaggy sandstone, shaly layers with ripple-marks and worms. . . . .	14

	Feet.	
Fossiliferous limestone. . . . .	8	
Blue-grey clay shale. . . . .	28	
Thin-bedded, fossiliferous limestone. . . . .	8	
Blue-green, clay shales, limestone bands with fossils. . . . .	105	
Thin-bedded limestone, fossils. . . . .	8	
Blue-green, clay shales . . . . .	10	
Sandstone, ripple-marks and worms. . . . .	12	
Blue-green, clay shales, limestone bands with fossils. . . . .	90	aneroid
Thin-bedded limestone, shaly, argillaceous. . . . .	25	
Blue-green, clay shales, bottom not exposed. . . . .	..	
	605	

The limestone beds which form the chutes of Peace river are correlated with some of the limestone bands in this section. The same horizon which is represented by the Alexandra Falls section is exposed in the walls of the canyon of the Liard which are 200 to 400 feet high. These begin 25 miles above the mouth of that river. *Spirifer disjunctus* is one of the most abundant and characteristic species found in this portion of the upper Devonian section which has been called the Hay River shales and limestones in the Great Slave Lake district. Beds corresponding to this horizon form the higher beds of the long ridge which separates Root river from the Mackenzie. They also outcrop 7 miles below Wrigley on the west bank of the Mackenzie, a few miles below Norman on both banks of the Mackenzie, near the mouth of Oil creek, and at various other localities. The top of the oil well 40 miles below Norman starts in beds of this horizon.

The limestones and shales which outcrop along Athabaska and Clearwater rivers appear to belong to the upper Devonian series but represent a very different faunal and lithological facies from that shown in the sections to the west and north. The outcrops of these beds which are exposed between Firebag river and McMurray at frequent intervals show a number of low arches which are seldom more than a few hundred yards across. The Tar sand or McMurray formation of the Cretaceous overlies the Devonian beds along Athabaska and Clearwater rivers.

### *Triassic*

Limestones, sandstones, and shales carrying a marine Triassic fauna are exposed on Liard and Peace rivers and on Pine River South. F. H. McLearn,<sup>1</sup> who has made an examination of the section on Peace river, states that dark purple limestones, hardened sandstones, and shales outcrop at Parle-pas rapid and on the south bank of the Peace 2 miles below the mouth of Ottetail river. About 4 miles above Fish creek on the north bank the strata are steeply inclined to the west. At the mouth of Twentymile creek there is a second and probably a lower Triassic horizon, the rocks consisting of limestones, sandstone, and shale. The entire series is quite thick and is probably all of marine origin.

Dawson recognized hard, black, calcareous shales of Triassic age on the upper part of Pine River South, and McConnell collected fossils from beds of this age on Liard river. For a description of the Triassic rocks on Liard river see pages 80 and 81 of this report.

<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1917, p. 16 C.

## Cretaceous

Sandstones and shales of Cretaceous age are of wide distribution in the southern and northern parts of the region drained by the Mackenzie.

In the southern part they extend from the Rocky mountains east to beyond the Athabaska, being exposed for many miles up Clearwater river and other tributaries from the east. Southward they reach beyond the 49th parallel of latitude. Their northern boundary crosses Athabaska river a little above Firebag river and crosses the Peace a short distance above Vermilion falls. They are cut through to the underlying Devonian limestone by Hay river at a point 33 miles above Alexandra falls. The 700- to 800-foot escarpment lying 30 miles north of lake Bistchô may be composed of Cretaceous rocks. The formation as exposed on Liard river extends from a point a few miles below Fort Liard to many miles above the mouth of Fort Nelson river. On the Fort Nelson and its tributary, the Sikanni Chief river, shales and sandstones occur.

In the northern part of the Mackenzie basin Cretaceous rocks occur in long stretches along the river below the mouth of Dahadinni river, along the upper course of Great Bear river, and around the west and north sides of Great Bear lake. The Cretaceous rocks outcrop also in the Mackenzie below old Fort Good Hope and in the basin of Peel river.

Following is a correlation table of the Cretaceous formations exposed on Athabaska, Peace, and Smoky rivers.<sup>1</sup>

System		Group	Athabaska section	Smoky-Peace section	
Cretaceous	Upper	Montana.		Wapiti.	
			Upper La Biche.	Upper shale.	
			Lower La Biche.	Bad Heart sandstone. Lower shale.	
		Colorado.	Pelican sandstone.	Dunvegan.	
			Pelican shale.	St. John.	
	Lower	Lower Cretaceous.		Grand Rapids.	Upper sandstone. Middle shale. Lower sandstone.
				Clearwater.	} Loon River.
				McMurray.	

Lower Cretaceous is here given the tentative interpretation of pre-Cenomanian Cretaceous. This is pre-Dakota in terms of the North American interior Cretaceous.

The sediments on Athabaska river are nearly horizontal, dipping to the south only a few feet a mile, so that in descending the river each formation emerges from beneath the overlying one in the order named in the table.

The McMurray sandstone is prevailingly arenaceous and is rather coarse-grained. Large portions are impregnated with bituminous matter (Plate XII A and B) forming the so-called tar sands or bituminous sands. The formation

<sup>1</sup> McLearn, F. H., Geol. Surv., Can., Sum. Rept., 1918, p. 2 C.

is exposed along the Athabaska from Boiler rapid to below Calumet river and along the valleys of tributary streams. It has a thickness of 110 to 180 feet. The top of the formation is placed at the base of a bed of green sandstone immediately above which the marine fauna of the Clearwater formation appears. It contains lignite seams and fragments of fossil wood and carries a small invertebrate freshwater fauna.<sup>1</sup>

*The Clearwater formation* consists of soft grey and black shales and grey and green sandstones and contains some hard concretionary layers. It has a thickness of 275 feet, first appears 5 miles below Grand island, and extends down stream above the McMurray sandstone. It carries a marine fauna.

*The Grand Rapids formation* is a sandstone 280 feet thick. It is first exposed 3 miles above Joli Fou rapid, and below Grand rapids forms almost continuous cliffs for miles. The upper part carries thin coal seams and is of subaerial origin; the lower part is highly concretionary, and the large concretions carry a marine fauna.

*The Pelican shale*, which has a thickness of 90 to 100 feet, is a black shale that first appears near Stony rapids and is a conspicuous feature for many miles down the Athabaska. It thins out toward the northwest, being only a few feet thick on Moose river and not recognized on the north end of Birch mountain. It carries poorly preserved species of *Inoceramus*.

*The Pelican sandstone* appears from beneath the La Biche shales at the mouth of Pelican river and forms a low cliff in all the exposures between Stony rapids and Grand rapids. It is 35 feet thick and is in general conspicuously white. A species of *Inoceramus* is found at the top.

*The La Biche shales* overlie the Pelican sandstone and extend up the Athabaska a few miles beyond the mouth of Pembina river, and up Lesser Slave river into the country surrounding Lesser Slave lake. The shales are also exposed in Birch mountain, an erosion plateau lying to the west of the lower part of Athabaska river. A section at Athabaska, as exposed in the bank and revealed by boring, consists of 15 feet of yellowish sandstone at the top, 165 feet not well exposed, and 1,090 feet of grey and blackish shales. These are succeeded downward by Pelican sandstone.<sup>2</sup>

*The Edmonton formation* consists of yellowish and greyish, flaggy and massive sandstones, often holding large concretions, and alternating with greyish and dark clays and shales. These sandstones, clays, and shales carry seams of lignite and are practically horizontal. The formation extends in a broad belt eastward from the foothills nearly to the junction of the Pembina and the Athabaska. Sediments that may belong to this formation are well exposed in the plateaus south of Lesser Slave Lake.<sup>3</sup>

There are at least 650 feet of strata in these hills that may be placed in the Edmonton formation, and a section of over 500 feet has been measured along Driftpile river. The top of the Edmonton is placed where there are two seams of coal, 20 inches and 21 inches thick, separated by 8 feet of shale, at an elevation of 3,300 feet. The base is not exposed but the character of the beds and the presence of a coal seam at an elevation of 2,650 feet are indicative of the Edmonton. This formation is overlain by the Paskapoo formation of Tertiary age.

<sup>1</sup> McLearn, F. H., Geol. Surv., Can., Sum. Rept., 1916.

<sup>2</sup> Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. XII, p. 14 A.

<sup>3</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 53 D.

J. A. Allan states that he did not observe the Bearpaw formation in the parts of this plateau examined by him and that if it exists it does not exceed 100 feet in thickness.<sup>1</sup> Some distance below the Edmonton formation there are beds of freshwater origin containing seams of coal. These are given the local name of Sawbridge formation.

Martin mountain, which lies northeast of Lesser Slave lake and is 1,000 feet high, is composed largely of sediments that may be equivalent in part to the Edmonton in age. Fragments of lignite and sandstone are abundant on its lower slopes and a loose fragment of sandstone found at its base afforded specimens of freshwater shells.

The Cretaceous sediments of Athabaska river are nearly horizontal and rest upon the Devonian with an unconformity so slight that it can be detected only by examination of the contact for a distance of many miles. Between Grand rapids and Pelican rapids the dip is about  $5\frac{1}{2}$  feet per mile south. Between Pelican rapids and Athabaska the dip is about 10 feet per mile. This greater dip may be due, in part, to its southward direction, and may indicate that the true dip of the Cretaceous strata on the Athabaska is west of south. A low anticline crosses the river near Crooked rapids; the dip on each side is only 3 or 4 feet a mile. Below McMurray the strata are probably nearly horizontal and may have a slight north or northeast dip.

The Cretaceous sediments exposed on Peace river rest upon Palæozoic rocks on the lower part of the river and on Triassic rocks near the Rockies. The following descriptions of the formations exposed on Peace and Smoky rivers are taken almost verbatim from reports of F. H. McLearn appearing in the Summary Reports of the Geological Survey for 1917 and 1918.

*Loon River Formation.* The Loon River shales are exposed on the valley sides from Vermilion chutes to near Brown's trading post, and north and east of the great horseshoe bend underlie the plateau adjacent to the river. They consist of dark blue to dark grey, friable weathering shale with a few rounded or flattened ironstone concretions. To the south, where they are penetrated by the wells of the Peace River Oil Company, they are more arenaceous, particularly near the base. Thus, in well No. 1 the following section rests on the limestone.

	Feet.
Shale.. . . . .	—
Sandstone.. . . . .	70
Shale.. . . . .	53
Sandstone.. . . . .	65
Shale.. . . . .	12
Sandstone.. . . . .	26
Shale with concretions and bands of ironstone.. . . . .	51
Palæozoic limestone.. . . . .	—

In No. 2 well, about  $1\frac{1}{2}$  miles south of No. 1, the 70-foot bed of sandstone has increased to 106 feet and the 53-foot bed of shale has decreased to 14 feet. Both wells also show a number of smaller beds of sandstone in the upper part of this formation, which are not present in the exposures downstream. Along the upper contact with the Peace River sandstones there is much replacement laterally of sandstone by shale, so that the contact rises stratigraphically northward. As exposed on the river in the north the even bedding and marine fossils point to a marine origin. It is possible, however, that the thick sandstones near the base

<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1918, p. 11 C.

of the formation in the south may be of non-marine origin, like the tar sands of the Athabaska at the same horizon. At the great horseshoe bend the thickness is 400 feet (estimated) and to the south in the oil wells, 1,100 feet. The Loon River formation is correlated with the McMurray and Clearwater formations of Athabaska river.

*Peace River Formation.* The rocks of the Peace River formation outcrop on both sides of the valley from a point about 14 miles above Carcajou point to Peace River. Where they are typically developed and exposed, they form steep valley-walls, the "Ramparts of the Peace." The formation consists of two sandstone members, with an intervening shale member, and where all three outcrop, the sandstone components give rise to two cliffs, separated by a bench on the shale. In its southern development the upper sandstone is made up of massive, white-to-cream, crossbedded sandstone. The few concretions present are thin and horizontally extended. A discontinuous lignite seam is found near the top at some localities. The surface of the cliff walls weathers into an arabesque of hollowed and bossy sculpture. The thickness of this upper sandstone in the south is 130 feet, but due to replacement by shale above, it thins northward and near the mouth of Cadotte river is only 90 feet thick. At this locality the upper, massive, crossbedded, freshwater sandstone of the south is replaced by bedded sandstone and shale with marine fossils. Both the thickness and arenaceous content continue to decrease northward until the entire member is replaced by shale; so that the contact with the St. John shale descends stratigraphically in that direction.

The middle shale member is made up of blue black, friable shale without fossils, but probably is of marine origin. The thickness is 30 feet.

The lower sandstone member differs considerably in structure and lithology from the upper. At the top it is characteristically massive and crossbedded and contains large spherical concretions similar to those of the lower part of the Grand Rapids sandstone of the Athabaska section. This passes down into bedded sandstone and shale. The shale is thin-bedded at the base and carries marine fossils. The top may be subaerial, but the lower part is certainly marine. The contact with the Loon River shales is arbitrarily chosen, being marked by a gradual transition from bedded sandstone and shale to shale below. South of Brown's trading post the thickness is about 160 feet, 7 miles below the mouth of Battle river it is 80 feet thick, and to the north it is only about 20 feet thick. Both this formation and the Loon River have a common fauna and this is now being studied. The affinities of this fauna are Lower Cretaceous and pre-Dakota, taking Cenomanian as the base of the Upper Cretaceous. The formation is correlated with the Grand Rapids formation of Athabaska river. As to Dakota there are three possibilities; it is represented by the top few feet of the Peace River sandstone; the lowest beds of the St. John are its marine equivalent; or there was no deposition in Dakota time.

*Bull Head Mountain Sandstone.* The Bull Head Mountain formation consists of a thick series of strata of freshwater origin lying between the Triassic shale below and the St. John shale above. It appears first in the canyon midway between Deep and Johnson creeks and continues to the west as far as Twenty-mile creek. As a result of the preliminary examination, this series of rocks may be divided into two members. The upper member consists of sandstones, shales, and coal beds and is well exposed in the canyon and on Gething and Johnson creeks. The lower part is made up of massive, coarse, crossbedded sandstones



and is exposed at the head of the canyon, on Portage and Bull Head mountains, and the high hills to the west. The sandstones overlying the *Pseudomonotis* beds about 4 miles above Fish creek probably represent the base of this formation. No fossils have been found in the lower part, but a few plants were collected in the upper coal-bearing shales and sandstones. These include a few cycads, conifers, etc., and a single specimen of a dicotyledon. Though it is not possible now to make any definite correlation with southern Alberta, the plant association of this flora suggests that of the lower part of the Blairmore formation of the Crowsnest district. The rich angiosperm flora (Dakota), however, that characterizes the top of the Blairmore is not found here. The Bull Head Mountain formation should be correlated with the Peace River, and probably also the Loon River formations of the eastern succession, since it occupies the same stratigraphic position; it is, therefore, of Lower Cretaceous age.

*St. John Formation.* The St. John shales form the gentle valley slopes above the cliffs made by the Peace River sandstones and underlie the adjacent plateaus, from the great horseshoe bend in the north to some distance south of the town of Peace River. There the Dunvegan sandstone comes in and underlies the plateau for some distance to the south. The St. John shale, however, continues to outcrop along the valley sides southwestward to the bend near the mouth of Burnt river, but occupies lower and lower elevations above river-level in that direction. It consists largely of dark blue to grey, friable shale with occasional rounded or banded ironstone concretions. At Peace River the formation is estimated to have a thickness of 560 feet. The Dunvegan sandstone and Smoky River shales overlie the St. John shales in the direction of Dunvegan.

The St. John formation is exposed farther west, and in the vicinity of Hudson Hope is found to be very much thicker than at Peace River. It embraces all the strata lying between the Bull Head Mountain below and Dunvegan sandstones above. It consists of two thick shale members separated by a thin sandstone member. The lower shale unit consists of 800 feet of dark, thin-bedded, slightly arenaceous shale, and first appears in the canyon about midway between Johnson and Deep creeks. It is well exposed on the Hudson Hope anticline, in the cliffs at Hudson Hope, and in the lower part of Maurice creek. Below the Gates the structure carries it below river-level. The thin, even bedding points to marine conditions, although no fossils have so far been found.

The middle sandstone consists of 50 to 80 feet of massive, crossbedded sandstone with vertical rootlets and prostrate stems and evidently represents temporary subaerial delta conditions. It forms steep-sided islands and cliffs at the Gates and above Hudson Hope, and outcrops in the Maurice Creek gorge.

The upper shales are first seen at Deep creek. To the Gates they occupy the valley sides above the middle sandstone. From there to Cache creek and from near King's ranch to below North Pine river they underlie the entire valley slope and from Cache creek to below King's ranch and from near the mouth of Kiskatinaw river to below Montagneuse river they occupy the part of the valley side below the Dunvegan sandstone. They also underlie the plateau north of the river from the foothills to the Cache Creek escarpment and the plateau south of the river as far east as the South Pine at least. From the Gates to a little below the mouth of the Kiskatinaw river a complete section of the upper shale is obtained owing to the east dip. Below the Gates it is made up of thin-bedded, dark, hard, and friable, shale with banded concretions of ironstone. Fossil-bearing, dark, friable shales with concretions are found near river-level from a

few miles below the mouth of Cache creek to within about 4 miles of North Pine river. Overlying this and appearing within about 2 miles of the river are black, paper-thin shales without fossils. Above this again come dark, thin-bedded, arenaceous shales with several large sandstone lenses. Downstream and higher are thin-bedded sandstone and shale to the contact with the Dunvegan sandstone. Farther downstream there is much lateral replacement of sandstone and shale along this contact. The thin, even bedding and marine fossils point to marine conditions of deposition. The upper shale member is estimated to have a thickness of 1,300 feet in the vicinity of Cache creek.

The small fauna of this formation is correlated with that of the Colorado group of the Upper Cretaceous.

*Dunvegan Formation.* The Dunvegan sandstone first appears in the escarpment at Cache creek, above Fort St. John, but a few miles downstream the higher elevations upholding this formation recede toward Charlie lake. It reappears in high hills in the north bank a little below the mouth of Kiskatinaw river. Rapidly descending on the valley sides, it forms cliffs to within a short distance of river-level. Below Montagneuse river and continuing past Dunvegan it outcrops to river-level. The formation is made up of light, massive, cross-bedded, soft sandstones with large flat concretions, and weathers into castellated forms. The crossbedding is on a scale of about 2 feet, truncated above, tangential below. Grains consist of quartz, feldspar, a little mica, and a black mineral. Other areas of this formation are more argillaceous and locally thin-bedded. A thin lignite seam in the sandstone varies in thickness but never exceeds 6 inches. There is also a rather prominent bed of shelly limestone, chiefly of freshwater shells, in the cliffs below Montagneuse river and below Dunvegan. The cross-bedded structure, coal beds, and freshwater fossils point largely to subaerial conditions of deposition, but the presence of *Inoceramus* and *Ostrea* indicates partial brackish water conditions, and probably the sea was not far away at any time. The formation has a thickness of about 530 feet. Both above and below it exhibits gradational contacts with continuous formations.

On Smoky river the Dunvegan formation underlies the higher valley sides and adjacent plateaus from Sixmile point to Racing creek, and the lower valley sides from Racing creek to Smoky at the railway crossing. Thick zones of subaerial, concretionary, massive and crossbedded sandstones with beds of subaerial shale alternate with thick zones of thin-bedded sandstone and shale which may in large part be of marine origin. The estimated thickness below Smoky is 440 feet.

The Dunvegan formation is correlated with the Pelican sandstone of Athabaska river.

*Smoky River Formation.* The Smoky River formation succeeds the Dunvegan on Smoky river. It underlies the higher valley sides and adjacent plateaus from about 12 miles below Racing creek to Smoky, the entire valley sides and adjacent plateaus from Smoky to within about 10 miles of Bad Heart river, and the lower valley sides from Bad Heart river to within about one mile of Kleskun creek. The Smoky River formation may be divided on lithological grounds into three members, a lower shale, a middle sandstone—the Bad Heart sandstone—and an upper shale. The lower shale and Bad Heart sandstone members are referred to the Colorado group and the whole or a part of the upper shale member to the Montana group. The lower shale consists below of paper-thin carbonaceous shales with concretions; above are dark, friable shales with concretions and at

the top shale and thin-bedded sandstone and shale. The Bad Heart sandstone member consists of 10 to 25 feet of coarse sandstone, weathering reddish brown. It stands out prominently in all the cliffs from Puskwaskau river to within a few miles of the Little Smoky and forms a horizontal, frieze-like band in the cliff walls of shale.

The higher part at least of the upper shale member of the Smoky River formation is Montanan. The upper shale member is made up of dark, friable shale with thin bands of sandstone near the top; ironstone concretionary bands are present. The thin banding and marine fossils indicate marine deposition. The thickness is 300 feet.

*Wapiti Formation.* The Wapiti succeeds the Smoky River formation and is intermittently exposed on Smoky river from Bezanson almost to the mouth of Bad Heart river. On this part of the Smoky there is a thickness of 900 feet and its upward extension is not known. The sandstone beds are thick, massive, and crossbedded. They contain rootlets and, in places, flat concretions. The shales vary from a couple of feet to over 50 feet in thickness, are grey to dark carbonaceous, and show vertical rootlets. A coal bed with a maximum thickness of 4 inches occurs 580 feet above the base and a second coal seam 3 inches to 4 inches thick, 180 feet above the base. This formation is evidently of subaerial origin. The sandstone walls occasionally weather into grotesque forms; the flat concretions form caps to detached or partly detached pillars and irregular buttresses.

The Wapiti occupies the stratigraphic position of the Foremost and Pale beds of the Belly River series of southern Alberta, but the upward range of this formation is not at present known.

The following paragraph by G. M. Dawson<sup>1</sup>, descriptive of the rocks of Pine River South and Table mountain, is of interest.

“In the Pine River cañon, the rocks of this subdivision are flaggy sandstones, often brownish-grey in colour and false-bedded or ripple-marked, greenish-grey, fine-grained sandstones and black, soft, argillaceous sandstones and shales holding plant impressions, also occur. In the valley of a small stream which cuts the bank on the south side of the cañon, not far above the river level, Mr. Selwyn, in 1875, found, in alternating strata of sandstones and shales, four thin seams of coal which in descending order are—six inches, eight inches, two feet, and eight inches thick. A number of fossils were also found in the associated beds, consisting of leaf-impressions and shells. ‘The former occur chiefly in beds below the coal seams, and the latter in the intervening sandy shales, and in the ferruginous and calcareous concretionary nodules which accompany the latter.’ These coal seams and the associated beds are at least 1,700 feet below the sandstones of the summit of Table mountain, and as the beds are nearly horizontal, this difference in elevation must closely correspond with the actual thickness of the rocks. For a portion of the ascent of Table mountain, however, the rocks are not seen, though about 200 feet thick of sandstone caps the hill. It is, therefore, uncertain whether the subdivision classed as the Upper Shales<sup>2</sup> may occur in the concealed interval and the sandstones at the summit represent the Upper Sandstone<sup>3</sup> series, or whether—as is perhaps more probable—the entire thickness of the rocks from the edge of Pine river to the summit of

<sup>1</sup>Geol. Surv., Can., Rept. of Prog., 1879-80, p. 117 B.

<sup>2</sup>Smoky River.

<sup>3</sup>Wapiti.

Table mountain should be classed as belonging to the Lower Sandstones,<sup>1</sup> which in this case must here have a very great thickness. In the sandstones of the summit of the mountain, numerous specimens of *Inoceramus altus*, a species previously noted, in beds supposed to represent the Pierre group in Wyoming, were found by Mr. Selwyn."

McConnell gives the following description of the Cretaceous formations of the Liard and Mackenzie rivers.<sup>2</sup>

"Fossiliferous Cretaceous beds were not recognized in descending the Liard until the plateau belt which borders the eastern foot-hills was reached. Below Fort Halkett, west of the mountains, a band of soft, dark shales crosses the river, which may be in part Cretaceous, but no fossils were found in it. The eastern foot-hills are built of a great series of alternating shales and sandstones, with some limestones, all folded closely together, which resemble those found in the foot-hills farther south, and, like them, probably consist largely of Cretaceous rocks, but it was found impossible on a hasty trip along one line to separate these from the Triassic, or from the shales which cap the Palæozoic system, owing to the lithological similarity which prevails throughout. East of the foot-hills the convolutions gradually cease and the section becomes more legible. The beds here consist of soft, finely laminated shales, interstratified with a few beds of sandstone and ironstone. They have a minimum thickness of 1,500 feet. The shales yielded some fossils among which were several specimens of *Placenticerus Perezianum*, one of the characteristic fossils of series C. of the Queen Charlotte islands. With this were species of *Camptonectes* and *Inocerami*. Near the eastern edge of the plateau belt the shales are overlain by massive beds of rather soft sandstones and conglomerates, the thickness of which was not ascertained. The conglomerates are affected by a gentle easterly dip, and descend to the level of the river in the course of a few miles. From the point at which they disappear to the eastern edge of the Cretaceous basin, the rocks consist of dark fissile shales, crumbly sandy shales, and sandstones, but the exposures along the valley are infrequent, and the succession soon becomes obscure.

"The Cretaceous section along the Liard thus shows two great shale and sandstone series separated by a heavy band of sandstones and conglomerates. The lower shales, from the imperfect fossil evidence at hand, and also from their lithological character, may be referred tentatively to the horizon of the Queen Charlotte Islands or Kootanie formation, the upper shales to that of the Benton, while the intervening conglomeratic band probably represents the Dakota. The lithological succession of the Cretaceous beds here is almost identical with that which obtains in other parts of the Cordilleran belt north of the International Boundary and on the Queen Charlotte islands<sup>3</sup> and shows that similar conditions of deposition prevailed at the same time over this whole area.

"The Cretaceous rocks cross the Liard with a width of over a hundred miles, and north of the river enter a bay in the mountains, the extent of which to the northwestward is not known; southwards they are connected with the great Cretaceous basin of the plains.

"Fifteen miles below Fort Liard the Devonian limestones rise to the surface, but the junction between them and the overlying Mesozoic rocks is concealed, and I was unable to ascertain whether the older beds continue to the

<sup>1</sup> Dunvegan.

<sup>2</sup> Geol. Surv., Can., Ann. Rept., vol. IV, pp. 19 D-21 D.

<sup>3</sup> Am. Jour. Sc., vol. XXXVIII, p. 120.

eastern edge of the basin or are here overlapped by the Upper Cretaceous. It is probable, however, that the latter is the case.

"The plains bordering the lower part of the Liard and the upper part of the Mackenzie rest on Devonian limestones and shales, and Cretaceous rocks were not detected in descending the latter stream until the Dahadinni river in latitude 64 degrees north was reached. They consist here of a couple of hundred feet of dark grey shales and sandstones. They are exposed along the valley for ten or twelve miles, and are then concealed by the boulder clay, but probably continue under the latter as far as the Tertiary basin at the mouth of Bear river, a distance of fifty miles. The Cretaceous beds here occupy a depression between two high ranges of limestone mountains and cannot have a greater width than ten or fifteen miles. They have been separated from the Cretaceous beds which form the western shores of Great Bear lake by the elevation of the Mount Clark range.

"Forty miles below (Great) Bear river the Cretaceous beds reappear on the banks of the Mackenzie, and with the exception of one break of a couple of miles where they have been removed by denudation, underlie the valley all the way to the Ramparts, a distance of ninety miles. The fossils obtained from this area and from the one above Great Bear river consist of fragments of Ammonites and Inocerami, too imperfect for specific determination.

"A hundred and twenty miles below the Ramparts, the Mackenzie enters a third Cretaceous area, and the largest one on the river. Cretaceous beds appear in the banks a short distance below old Fort Good Hope and extend down the Mackenzie to the head of its delta, and westwards across the Rocky mountains and down the Porcupine to about longitude 139 degrees west. They consist on the Mackenzie of coarse shales interstratified with some sandstones and fine-grained conglomerates; in the mountains of several thousand feet of barren sandstones and quartzites underlain by dark shales; and on the Porcupine of the same two series underlain by a great thickness of alternating shales, sandstones, and conglomerates, holding *Aucella mosquensis* var. *concentrica*. The intermediate dark shales are probably of Benton age, while the lower division so far as the fossil evidence goes, represents the Queen Charlotte Island formation and the Dakota."

Coarse-grained sandstones are exposed along Fort Nelson river for 12 or 14 miles up from a point 12 miles above its mouth. Black shales are seen 20 miles above Fort Nelson; farther upstream these are overlain by sandstone, and at a point 60 miles above Fort Nelson they disappear at the water's edge beneath the sandstone. On Sikanni Chief river, 45 miles above its junction with the Fort Nelson, the banks are composed of shale and sandstone. Farther up, the river has cut a canyon, which at a point near the headwaters of Pine river, is 1,100 feet deep. The lower 475 feet of strata here exposed consist of black and grey shale with some thin layers and masses of clay ironstone. This is succeeded upward by sandstone. Cliffs of this sandstone occur on Pine river and other streams between Sikanni Chief and Peace rivers.<sup>1</sup>

Some soft sandstones and conglomerates, probably of Cretaceous age, are exposed for a few miles along the north bank of Gravel river about 25 miles from the Mackenzie.<sup>2</sup>

The greater portion of the basin of Peel river below Wind river is underlain by soft Cretaceous shale and sandstone. Between the lower canyon and Snake

<sup>1</sup> Ogilvie, Wm., Dept. of Interior, Ann. Rept., 1892, pt. 7.

<sup>2</sup> Keele, J., "A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and Northwest Territories," p. 40, Geol. Surv., Can., 1910.

river the Peel has cut a valley 500 to 700 feet deep in these sediments, and about 5 miles below the canyon a section in the bank shows 200 feet of yellow and red shales, which towards the base are interbedded with layers of sandstone. This is succeeded downward by massive sandstone 50 feet thick, underneath which occur about 150 feet of very fissile, rusty, pyritous shale. The glacial drift in this section is about 40 feet thick. Northward the shales gradually increase in thickness until they predominate over the sandstones. The sediments lie in gentle undulations. A good section of Cretaceous rocks is obtained in mount Goodenough, which is 3,000 feet high and lies to the west of the Mackenzie delta, 2 miles from Huskie river, the western branch of the Peel. The strata are horizontal or only slightly folded. "At the base is a thick series of black shales, which towards the top contain beds of very hard clay ironstone. These weather red, and the outcrop can be traced by its colour for miles along the eastern face of the mountains. These red beds contain remains of Ammonites, while the underlying and enclosing black shales are also fossiliferous. The shales are gradually replaced upwards by argillaceous sandstones, and these again by siliceous sandstones. These latter become metamorphosed to quartzites and constitute the upper members of the series."<sup>1</sup>

Nearly horizontal Cretaceous sediments surround the western and northern portions of Great Bear lake, reaching to within 30 miles of Fort Confidence, and extending down Great Bear river to within 7 or 8 miles of its mouth, being replaced, however, at the rapid by Palæozoic strata that form the range of mountains cut by the river. Around the lake there are few outcrops of rocks of this formation. Shales and sandstones are exposed along Smith bay, and the Scented Grass hills represent a low anticline, composed of hard sandstone, which forms Gros Cap peninsula. Above the rapid on Great Bear river there are numerous exposures of rocks in which some fossils are found.<sup>2</sup> The western part of the peninsula north of McTavish bay is probably underlain by Cretaceous sediments, and Richardson's notes indicate that Cretaceous sediments are exposed in Grizzly Bear mountain which forms the promontory between McVicar and Keith bays.

### *Tertiary*

Tertiary sediments occupy a few small areas in the Mackenzie basin.

The Paskapoo formation is exposed on Pembina river near longitude 115 degrees west, where a thickness of 50 feet or more of yellowish-grey sandstones overlies 70 feet of concealed rock resting upon a seam of coal. The formation extends some distance to the west.<sup>3</sup> Shales and sandstones of this formation are exposed on the summits of Swan hills south of Lesser Slave lake.

"Tertiary beds occur at the mouth of (Great) Bear river and occupy a basin of about thirty to forty miles in length and twenty to thirty in breadth. They rest unconformably on the underlying Cretaceous shales and Devonian limestones. They are lacustral in origin and consist largely of discordantly bedded sand, sandy clays, clays, and gravels. Beds of purely argillaceous material, usually somewhat plastic in character, are also present, and seams of lignite and carbonaceous shales not infrequently constitute a considerable portion of the section..... The beds have an anticlinal attitude on the whole, but are usually nearly horizontal. They have a minimum thickness of 600 feet."<sup>4</sup>

<sup>1</sup> Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XVI, p. 46 CC.

<sup>2</sup> Bell, J. M., Geol. Surv., Can., Ann. Rept., vol. XII, p. 25 C.

<sup>3</sup> McEvoy, James, Geol. Surv., Can., Ann. Rept., vol. XI, p. 24 D.

<sup>4</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. IV, p. 22 D.

A small area of Tertiary sediments occurs on Peel river in the vicinity of Wind and Bonnet Plume rivers and reaches from 20 to 30 miles up the valleys of these rivers. The rocks consist of sandstones and clays carrying beds of lignite. These have an unconformable relation to the underlying strata, and have been gently folded into a number of anticlines and synclines.<sup>1</sup>

### *Pleistocene and Recent*

With the exception of the higher points of the Rocky and Mackenzie mountains on its western side, the whole basin of Mackenzie river was overridden by glacial ice during a part at least of the Pleistocene period. Ice appears to have entered the basin from two sides, namely, from the Keewatin centre on the east which is believed to have occupied a position on the northwestern side of Hudson bay, and from the Cordilleran ice-sheet on the west, the centre of which lay to the west of the Rocky mountains in the northern part of the province of British Columbia. At the same time tongues of ice flowed down the valleys on the eastern side of Mackenzie mountains, rising from a confluent ice-sheet which lay on the western slope of those mountains and formed the northern extension of the Cordilleran ice-sheet.<sup>2</sup> Keele states that "the valley of the Mackenzie river was occupied by an ice-sheet of considerable thickness which pushed up the valley of the Gravel river before the ice from the Cordilleran glacier began to pour down."

Ice from the western sources entered the basin of Mackenzie river in the form of valley glaciers which flowed down the valleys now occupied by the western tributaries of the river. Keele has estimated that a thickness of 2,000 feet of ice occupied the valley of Gravel river in its lower part, and on Wind river, a tributary of the Peel, Camsell found that the maximum thickness of the ice in that valley must have been about 1,000 feet. Ice tongues also occupied the valleys of the Athabaska, Pine, Peace, and Liard rivers in the mountains and foothills portions of their courses and probably spread out as piedmont glaciers on entering the more level country of the plains.

On the eastern side, ice from the Keewatin centre invaded the Mackenzie basin as a continental ice-sheet, its encroachments gradually extending farther and farther westward until it joined with the ice from the western sources. From the evidence of striations and transported material the direction of movement of the Keewatin ice-sheet is shown to have been southwestward in the southern part of the basin and westward and even northwestward in the northern part. South of Athabaska lake, for example, the general course of the ice was south-southwest; immediately north of Athabaska lake it was southwest; and on Great Slave lake it was almost west. Farther north, in the valley of Mackenzie river, about latitude 66 degrees north, McConnell<sup>3</sup> noted evidence of a more northerly flow of an ice-sheet approximately 1,500 feet thick, which extended down the valley of the river and thence out to sea. Kindle found deep glacial grooves trending east and west in the limestone at an elevation of about 1,500 feet on mount Charles.

The results of glacial action in the basin of Mackenzie river are everywhere shown by the presence of various kinds of deposited material as well as by the eroded surfaces. Over a large part of the basin the effects of erosion are predominant, and over the remainder of the basin deposition of eroded and transported

<sup>1</sup> Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XVI, p. 41 CC.

<sup>2</sup> Keele, J., "A reconnaissance across the Mackenzie mountains," Geol. Surv., Can., 1910.

<sup>3</sup> Geol. Surv., Can., Ann. Rept., vol. IV, 1888-89, p. 27 D.

material prevails. The boundary line between the region of erosion and that of deposition follows more or less closely the boundary between the Precambrian and Palæozoic rocks.

The region of erosion is characterized by bare rock surfaces, rounded and glaciated by the passage of the ice-sheet over them. Deposited material is found in the hollows of the surface and consists mainly of boulder clay. Moraines, drumlins, eskers, sand-plains, and some curious drift hills called "ispatinows"<sup>1</sup> by J. B. Tyrrell occur here and there, but are not notably abundant.

In the central and western portions of the basin, where deposition is more evident than erosion, the surface is in general so heavily drift-covered that the older, underlying rocks are nearly everywhere concealed. The glacial deposits have not been uniformly distributed but are thickest in old, pre-glacial depressions, whereas on the ridges they become greatly attenuated. Inequalities have been reduced and a rolling topography developed.

Sections of the glacial deposits of the central portion of the basin show in many cases boulder clays usually underlain by stratified sands and gravels and frequently overlain by a second series of sands and gravels. Such sections occur frequently in the basins of Athabaska and Peace rivers and in the valley of the Mackenzie. The stratified sands and gravels, both below and above the boulder clay, are, according to McConnell,<sup>2</sup> evidently lacustrine in origin and were doubtless deposited in greatly expanded lakes near the ice front, both before the advance and immediately after the retreat of the ice-sheet, whereas the boulder clay represents the ground moraine of the ice-sheet itself. Thicknesses of these beds vary considerably. Sections of the boulder clay occasionally show a thickness of 250 feet and the sands and gravels over and beneath the boulder clay are in some cases fully 150 feet thick.<sup>3</sup> Kindle states that glacial drift 400 feet thick is exposed at Wrigley. Moraines are apparently fairly prevalent in this portion of the basin. McConnell<sup>4</sup> describes a prominent morainic ridge southwest of the west end of Great Slave lake as consisting of a "medley of steep-sided, interlacing hills and ridges, similar in appearance to those found on the Grand Côteau de Missouri of the plains" and evidently of like origin.

On the final retreat of the ice-sheet from the basin of Mackenzie river, lakes occupied not only the present lake basins but other large tracts of country which have since been filled up or drained. Filling of some of these lakes by the streams flowing into them is still in progress. Both the Peace and Athabaska rivers in the flood season carry a great deal of sediment and this is being deposited as fine sand, clay, or silt in their deltas, gradually filling up the western end of Athabaska lake. A former southern arm of Great Slave, which at one time extended up the valley of Slave river as far as Fort Smith, has already been filled with the same sort of material from Slave river. The Mackenzie itself carries some sediment in flood time and is building a great delta, the emerged portion of which is about 80 miles across its seaward side and 100 miles deep. The submerged portion extends in a broadening front far out into the Arctic ocean.

The rivers of the Mackenzie basin are very largely post-Glacial and have cut deep valleys into the Glacial and underlying Cretaceous shales and sandstones. In certain instances, as in the case of Little Buffalo, Hay, and Beaver

<sup>1</sup> Geol. Surv., Can., Ann. Rept., vol. VIII, 1895, p. 23 D.

<sup>2</sup> Geol. Surv., Can., Ann. Rept., vol. V, 1889-90-91 p. 61 D.

<sup>3</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. IV, 1888-89, p. 26 D.

<sup>4</sup> Op. cit., p. 25 D.



rivers, gorges several miles in length have been cut into Devonian limestones and shales to depths of 100 or 200 feet, and as in the case of Niagara falls and gorge, give a scale by which estimates can be made as to the time that has elapsed since the recession of the ice-sheet.

### *Section in Peace River Pass*

In a hurried reconnaissance through Peace River pass it was found that the rocks exposed along the pass consist principally of "greyish Palæozoic limestones striking in a northwesterly direction, and dipping persistently to the southwest. Repetitions of parts of the limestone series, caused by overthrust faults, occur at several points." No infolds of Cretaceous strata, such as occur farther south, were observed.

"Immediately east of the main range, exposures of yellowish-weathering, calcareous sandstone occur in the banks of the river. These are replaced going westward by greyish limestones dipping steeply to the west. The junction between the limestone and sandstone is concealed in the valley, but there is little doubt from the relative position of the two formations, that the contact is a faulted one and that the Palæozoic limestones of the mountains, here as elsewhere along the eastern boundary of the range, are thrust up over the Mesozoic rocks of the foothills.

"The limestones are fossiliferous, the fauna, so far as ascertained, being similar to the Banff or Devonian-Carboniferous division of the Bow River section.

"West of the fault, the limestones stand at a steep angle, the beds being fairly regular, but farther west they become greatly confused and show evidence of much disturbance. In the second range, the limestones are overlain by a band of dark *Monotis*-bearing calcareous shales and impure limestones of Triassic age. West of the Triassic band, a second fault brings the Banff limestones again to the surface, and the same limestones, probably repeated by faults, occur in the next two ranges. In the first of these, the Banff limestones and overlying Triassic beds have a regular westerly dip, but in the second, a line of strong disturbance is reached, and the strata as seen on the mountain sides are crushed into numerous subordinate folds.

"A fault of considerable magnitude crosses the valley west of the two ridges referred to above, and brings up limestones which were referred to the Castle Mountain group. West of this fault, the dips north of the river for some distance were too confused to follow, but south of the river, the beds, with the exception of one double fold, dip regularly westward until near Mount Selwyn. The limestones in this part of the range are mostly unfossiliferous and of the Castle Mountain type, but higher beds holding *Halysites* were found in one place.

"Mount Selwyn shows a sharp anticline on its eastern slope. The centre of the mountain is formed of almost vertical limestone beds, but going westward these are soon replaced by the quartzites, schists, and crushed conglomerates of the Bow River series. The latter are forced up over the limestones by a well-defined overthrust fault, running in a northwesterly direction.

"Mount Selwyn is flanked on the west by a small range composed partly

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<sup>1</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. VII, p. 32 C.  
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of the rocks of the Bow River series and partly of the schists of the still older Shuswap series, all dipping to the southwest. The latter overlie the former, but the cause of their superior position was not ascertained."

*Section on Liard River*

The following section along Liard river, from Dease river to the Mackenzie, is taken from McConnell's report of his traverse made in 1887.<sup>1</sup>

Three miles below the mouth of Dease river there is an exposure of soft, dark shales associated with friable shales and conglomerates probably of Tertiary age, and on a small island at the mouth of Hyland river there is an exposure of hard, whitish sandstone passing into quartzite and dipping northeast at an angle of 50 degrees. Six miles farther down, unconsolidated sands, sandy clays, and gravels holding small beds of impure lignite are exposed in a cut bank.

"The rocks in the Little canyon consist of dark and sometimes cleaved shales, holding large, flattened ironstone nodules, hard sandstones and quartzites, and some beds of fine-grained, hard, siliceous conglomerate. They are closely folded together and strike north 35 degrees west. No fossils were found in any of these beds, nor any definite evidence of their age obtained beyond the fact that the shales have a close lithological resemblance, both in appearance and composition, to those on Dease river, from which Dr. Dawson obtained graptolites of Utica-Trenton age."

A few miles below Little canyon the shales, sandstones, and conglomerates are replaced by shaly limestone. This is succeeded lower down the river by more massive varieties of limestone. Still lower down a range of hills extends in an irregular manner for some miles along the left bank of the river and rises to an altitude of 1,500 feet above the river, or 1,000 feet above the general plateau level. "The limestone of which the hills are formed is usually greyish in colour and rather compact, but passes in many places into a whitish, highly crystalline variety without distinct bedding. It has a general strike of north 15 degrees west. It is destitute of determinable fossils, but holds fragments of crinoid stems, and traces of brachiopods and trilobites."

Limestone outcrops are seen along the river to within a few miles of the mouth of Turnagain river. These limestones are often coarsely crystalline and cut by white calcite veins. "Other varieties show wavy lines projecting from weathered surfaces due to alternating magnesian and calcareous layers, and closely resemble in this respect the limestones of the Castle Mountain group as developed along the Bow River pass. In some places the limestone becomes shaly and impure, and is altered into an imperfectly developed schist."

The limestone is replaced several miles above Turnagain river by shales, sandstones, and conglomerates, that are exposed at many points as far as Whirlpool canyon, above Coal river. These rocks resemble those of Little canyon and are evidently of the same age. The shales are dark and finely laminated and are interstratified in places with the sandstones. The latter are lighter coloured than the former, are hard, and often pass into quartzite. The conglomerates are very fine-grained and consist principally of white, well-rounded, quartz pebbles, embedded in a siliceous matrix. Resting unconformably upon these beds at Cranberry rapids, a few miles above the mouth of Turnagain river, there is an exposure of soft shales and conglomerates, evidently of Tertiary age.

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<sup>1</sup> Geol. Surv., Can., Ann. Rept., vol. IV, pp. 33-58 D.

Lignite of inferior quality is brought down by Coal river, but although an examination was made of several miles of the bank its source was not discovered. The banks of the lower part of Coal river are low and consist of uncemented sands, clays, and gravel similar to the lignite-bearing beds above Little canyon. This formation is of irregular thickness, but of wide distribution, and fills depressions in the older rocks from the mouth of the Dease to the passage of the Rockies.

"The rocks observed along the river from Whirlpool canyon to the lower end of Brulé portage consist altogether of different varieties of limestone. This occurs in some places in massive beds, ranging in texture from compact to moderately crystalline. In other places it becomes very impure and shaly, and often passes into imperfectly developed calc schists. No fossils were obtained from it, but it has a close lithological resemblance to the limestone occurring above Cranberry rapids."

Dark shales, softer than those farther up the river and probably of Mesozoic age, are exposed near the mouth of Smith river and can be traced several miles down the Liard, where they are finally replaced by limestone. The main range of the Rocky mountains where cut by the river consists of a greyish and moderately compact limestone. The strata first met are horizontal, but a short distance farther down they assume almost vertical attitudes and apparently are folded in a sharp anticline. The limestones are exposed for 6 miles along the river and then become concealed by dark shales similar to those farther down from which Triassic fossils were obtained. Shales of Mesozoic age are thus found to occur on both flanks of the mountain.

In the foothills, which here have a width of 38 miles, the rocks exposed consist chiefly of shales with bands of sandstone, and occasionally some limestone. The shales undulate at all angles, and at the east end of Devils portage an anticline brings to the surface greyish, moderately crystalline limestone holding fragments of crinoids and other fossils. These limestones probably belong to the upper part of the Palæozoic series of the mountains. The shales are dark in colour, and as a rule are rather coarsely laminated. Fossils were collected at the Rapids of the Drowned, at Hell Gate, and at the lower end of the canyon above Hell Gate, and were referred by Whiteaves to the Triassic. "The localities from which Triassic fossils were obtained, extend along the river for ten miles, but it is highly probable that the rocks of this age have a much wider distribution than this and include the greater part of the barren shales above the Rapids of the Drowned, as well as those below Hell Gate. It will require, however, more time than could be spared on a rapid reconnaissance, to separate precisely the shales which cap the Palæozoic from those of the Trias, and the latter from the Cretaceous."

The plateau district to the east of the foothills consists of flat-lying Cretaceous shales. They are dark in colour, are soft and finely laminated, and are interstratified with small beds of sandstone and ironstone, and layers of ironstone nodules. Towards the eastern part of this plateau belt the shales along the river are overlain by massive beds of soft sandstone and conglomerate, which form a steep escarpment running parallel with the river.

The river leaves the plateau by a narrow gap a short distance above the mouth of Beaver river and enters much lower country, where occasional exposures occur of Cretaceous shale and sandstone and of Devonian shale and limestone.

*Section on Gravel River*

The following description of the rocks exposed on Gravel river is taken from Joseph Keele's "Reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon, and Northwest Territories."<sup>1</sup>

"The mountains of the watershed at the head of the Ross river are formed of alternating beds of dark, compact quartzite and grey shale and slate.

"About ten miles east of the divide some yellowish, crystalline limestones occur in low isolated cliffs along the embryo Gravel river, but the principal rocks are dark, sandy shales, striped grey slates, and micaceous sandstone or quartzose schists. Rocks of this character extend eastward to mount Sekwi, about fifty miles from the divide, and then end abruptly.....

"A radically different geological province begins at mount Sekwi, and limestones, dolomites, sandstones, and conglomerates, etc., of various bright colours, replace the sombre rocks to the westward."

The eastern part of mount Sekwi is composed of dove-coloured limestones. These pass into grey argillites and are interbedded with sandstone or quartzite. Farther east there is a section of over 2,000 feet of rather pure limestone. These rocks are of Silurian age and vary in attitude from nearly horizontal to vertical.

Purple and greenish argillites, followed upward by dolomite, calcareous sandstone, and limestone occur at the junction of the Natla and Gravel rivers. These beds, which are of Cambrian age, have a total thickness of 4,000 feet and are inclined at a low angle to the west. Dolomite forms a large part of this section.

Below the mouth of the Natla the mountains are composed of rocks quite different from the foregoing, beneath which they appear to dip. They are probably of Cambrian age and consist of

	Feet.
Brown, micaceous, sandy plates.....	1,100
Conglomerate .....	2,000
Coarsely laminated, hematite and siliceous slate.....	100
Dolomite and argillite .....	1,000

The conglomerates form the wall rock of Shezal canyon.

Below Twitya river the rocks composing the Tigonankweine range consist of 4,000 feet of alternating beds of argillite, dolomite, and limestone, succeeded upward by a sill of diabase, 100 feet thick, and 1,500 feet of sandstone. The diabase sill has an horizontal extent of several miles. This series, which is referred to the Ordovician system, lies nearly horizontal. The sandstones, whose prevailing colour is reddish, grow thicker towards the east and opposite the mouth of Nainlin brook are about 4,500 feet thick, forming the entire mountain mass. They extend down the river as far as Inlin brook where they are replaced by limestones.

These limestones are probably of Devonian age. They are more or less massive, are broken into several fault blocks, dip to the southwest, have low escarpments facing northeast, and constitute the eastern foothills of Mackenzie mountains. With decrease in the altitude of the foothills to the eastward the limestones become less tilted and broken, the bedding is thinner, and shaly layers appear. In some of these, fossils of Devonian age were found.

"About twenty-five miles from the Mackenzie some soft sandstones and conglomerates are exposed for a few miles along the north bank of the Gravel

<sup>1</sup> Geol. Surv., Can., Pub. No. 1097.

river; the beds are inclined slightly toward the west, and have a thickness of about 200 feet.

"The sandstones are coarse-grained and nodular, of yellowish or grey colour, grading into fine conglomerates, which are made up chiefly of black cherty argillite fragments." They are probably of Cretaceous age.

#### *Section on Peel and Wind Rivers*

In the section along Wind river, from Nash creek to the edge of the mountainous country, the following succession of rocks occurs in ascending order: ferruginous slates and argillites; limestones, and sandstones with some limestones; dark reddish conglomerate.

At the mouth of Nash creek the rocks consist of closely-folded black slates with remnants of the overlying limestone occurring in the synclines. They strike east and west across the valley of the river and dip at high angles or are vertical. Northward the limestone becomes gradually more dominant and the underlying slate appears only when brought up by an anticline. Fifteen miles below Nash creek, a coarse-grained, white sandstone is met overlying the limestone and slate. The strata are horizontal or dip at a low angle to the north. At this place the limestone is not so thick as farther up stream and appears to rest unconformably on the slate. From Bear river to the point where Wind river leaves the mountains, sandstone and limestone appear in a succession of gentle anticlines and synclines. A small body of dark reddish conglomerate overlies these on the edge of the slope.

On emerging from the mountains, Wind river enters a broad plateau. The level of this plateau is broken in places by several short ranges of mountains, which are really the foothills of the main range. The foothills area extends northward some distance beyond the east and west stretch of Peel river and eastward to Snake river. Almost in the centre of this area lies a large basin of over 500 square miles, occupied by slightly disturbed Tertiary rocks. This basin, which is almost completely enclosed by foothills, lies between Wind and Bonnet Plume rivers and extends southward from the Peel some 50 miles.

The geology of the foothills section is in marked contrast with that of the mountain section. Three miles from the base of the main range there are cliffs 150 feet high composed of slightly inclined beds of fine conglomerate holding fragments of fossil wood and ironstone nodules and merging into soft grey sandstone. The latter becomes feldspathic towards the top, and is overlain by boulder clay. These sandstones, which are probably of Cretaceous age, form cliffs on both sides of the river down to within 2 miles of Little Wind river.

The Illyd range consists of massive, grey, dolomitic limestones having an anticlinal structure. "Mount Deslaurier is a west-facing fault scarp, rising abruptly from the water's edge to a height of 850 feet. It is composed of about four hundred feet of dark reddish conglomerate, containing angular and water-worn fragments of limestone, quartzite, and other rocks; below this is a brecciated limestone, which, near the contact, also carries some foreign fragments. At the water's edge is some sandstone."<sup>1</sup> Mount Deception, standing at the junction of Hungry creek and Wind river, is composed of massive crystalline limestone. Below mount Deception the river enters the level country underlain by almost undisturbed Tertiary clays and sandstones.

<sup>1</sup> Geol. Surv., Can., vol. XVI, pt. CC, p. 26.

A seam of lignite 6 feet thick is exposed 12 and 14 miles below mount Deception. Four miles above Peel river a section is exposed showing 5 feet of rusty black slates overlain unconformably by 50 feet of sandstone, with eight seams of lignite one-half inch to 4 inches thick. Overlying this there is a thickness of 40 feet of gravel and boulder clay. One mile above Peel river the contact between the Tertiary sandstones and the underlying black slates is well exposed, the former dipping at a low angle to the east and the latter being vertical.

On Peel river, tilted, fine-grained slates extend from several miles above to three-quarters of a mile below the mouth of Wind river, where they are replaced and overlain by Tertiary clays and sandstones. The width of the Tertiary basin where it is crossed by the Peel is 13 miles. The formation consists of clays and sandstones carrying beds of lignite. It is gently folded into a number of anticlines and synclines. One lignite bed near the top is 30 feet thick and fairly persistent, being exposed at two points 4 miles apart with a shallow syncline between. It rises in an anticline, the top of which has been eroded away, and beyond dips again and disappears beneath the bed of Bonnet Plume river. It has been burnt for some distance along the bank of the river.

At the lower canyon the river cuts the same series of slates as are exposed in the upper canyon. A band of crystalline limestone apparently forming the base of the series is exposed at a point half-way through the canyon and at the lower end. No fossils were found in these rocks.

From the lower canyon to Snake river the Peel flows through a valley cut into soft shales and sandstones of Cretaceous age. Below Snake river argillaceous sandstones and clays are exposed, and below Trail creek soft shales, often pyritous, occupy a large section of the banks and are associated with a sandstone carrying fragments of Ammonites. The Peel leaves the plateau at Satah river and enters a low-lying, level country underlain by soft sandstones and some conglomerate. Only alluvial sands and clays are exposed below Fort McPherson.

#### *Section along Peel River Portage West of Fort McPherson*

"The Rocky mountains, along the Peel River portage, present features which differ greatly from those which characterize them farther to the south. They consist here essentially of two ranges, separated by a wide longitudinal valley, and flanked on either side by high plateaus. The eastern range has a width of seven miles, and its higher peaks were estimated to reach an altitude of 2,500 feet above the level of the pass, or about 4,000 feet above the sea. The western range is much narrower, and north of the pass does not exceed four miles in width, but spreads out somewhat more towards the south. The valley of Peel river, which skirts the eastern base of the range, is fully 1,200 feet lower than the valley of Rat river on the western side, and the drainage of the mountains is mostly towards the former.

"The geological section obtained is somewhat imperfect, as our scanty supplies allowed of no delay, but sufficient was learnt to show that the range has on the whole an antimonial structure, although the general anticline is obscured in places by subordinate folds, and is probably broken by faults. In the eastern plateau the beds are nearly horizontal, but approaching the mountains they incline greatly to the eastwards, and in the centre of the eastern range have dips of from 30 degrees to 70 degrees in the same direction. In the western range the same dip prevails, but the inclination is much less, and the beds flatten

out when the mountains are replaced by the elevated western plateau. The horizontal altitude is maintained for some miles, but before reaching the western edge of the plateau the beds bend down and dip gently to the west.

"No limestones were observed along this section, and the rocks consist of sandstones, quartzites, and shales, all of which are probably referable to the Cretaceous. At the starting point on Peel river the banks are formed of shales, interbedded with some hard sandstones holding carbonized fragments of wood and leaves. In the first fourteen miles the beds are concealed, but shales and sandstones are again exposed on the banks of the valley in which we made our first camp. Some fossils were collected here, among which is a *Discina* like *D. pileolus*, *Whiteaves*, a *Maetra* and a *Yoldia*, both of which are probably new, but the specimens are too imperfectly preserved to admit of specific determination. Six miles farther west, at the entrance to the "Gap," the trail passes over beds of a bluish, rather compact calcareous sandstone. The beds are coated in places with calc-spar, are highly ferruginous, and weather to rusty yellow. A *Cardium* and some other poorly preserved fossils were obtained here. In the valley of the river the sandstones are underlain by dark shales. After entering the mountains, only alternating sandstones and quartzites were seen. The beds of this series are greyish in colour, are evenly stratified, and are very uniform in appearance all across the range. They have an estimated minimum thickness of 5,000 feet, and may possibly greatly exceed this. The western plateau is built of compact, greyish sandstones, passing in places into quartzites, similar to those found in the mountains and evidently belonging to the same formation."<sup>1</sup>

#### STRUCTURAL GEOLOGY

In the Precambrian rocks of the Laurentian Plateau portion of the Mackenzie basin our knowledge of structure and structural relations is very imperfect and is limited to the region about Athabaska lake and the territory along the Tazin and Taltson rivers. Beyond this, little mention is made of structure in the reports of explorers.

Throughout the whole Precambrian portion of the basin, however, the same structural relations seem to hold in a general way. Great granite batholiths have been intruded into an older series of stratified rocks, of which there are now only remnants left. These two series have together suffered from severe orogenic disturbances, so that the stratified rocks are now tilted at high angles and the granites have in part become gneissoid. The remnants of the stratified rocks seem to be synclinal in structure and the strike ranges from northeast on Athabaska lake to north and even northwest on Taltson river. The trend of the gneiss conforms in a general way to the strike of the stratified rocks, and in certain localities there is much local contortion of the beds or foliation planes.

The younger rocks of the Precambrian, as illustrated by the Athabaska sandstone on the south shore of Athabaska lake and others on Great Slave lake, show little evidence of disturbance. The beds are horizontal or dip at very low angles. They are cut by later dykes which, however, have created little disturbance and effected only slight local metamorphism. There is massive jointing of the beds, but apparently little faulting.

In the Great Central plain there has been no igneous intrusion in the rocks outcropping at the surface, and little orogenic disturbance, so that the structure

<sup>1</sup> McConnell, R. G., Geol. Surv., Can., vol. IV, pp. 119 D-120 D.

is the result mainly of simple deposition of sediments on a comparatively even surface. The Devonian strata show slight undulations in the sections exposed on Athabaska river, but the trend of the undulations has not been determined and it is doubtful whether there is any uniformity of trend. On Peace river and the Slave, where these rocks overlie beds of gypsum of Silurian age, there is considerable local disturbance. The beds immediately overlying the gypsum are fractured and brecciated, and are thrown into a series of anticlines and synclines sometimes with dips as high as 70 degrees. The disturbance is believed to be due not to mountain-building forces but to the alteration of beds of anhydrite to gypsum and the consequent expansion as a result of that alteration. A gentle anticline crosses Great Slave lake from Pine point to Nintsi (Windy) point. In the lower part of Mackenzie river the Devonian rocks of the Great Central plain have been considerably influenced by the disturbances which elevated the Cordillera, and anticlinal structure is common. The folding and possible faulting that are expressed in such features as Franklin mountain, Bear mountain, and the ridges near the mouth of Carcajou river are related to the Cordilleran disturbances and their trend conforms in a general way to the trend of Mackenzie mountains.

The Cretaceous and younger rocks of the Great Central plain in the southern part of the basin are apparently undisturbed and in the sections exposed on Peace and Athabaska rivers the dip of the strata, except in the foothills, does not exceed a few feet per mile. The hills of Cretaceous rocks which rise out of the country between the Peace and Athabaska rivers, for example, Birch mountain, Buffalo Head hills, Pelican mountain, and Martin mountain, are believed by McConnell<sup>1</sup> to be due to erosion rather than to upwarping.

In the northern part of the basin parts of the Cretaceous of the Great Central plain have been involved to some extent, as has been the Devonian, in the Cordilleran disturbances, and the beds are arched into low anticlines striking north and south and broken by faults. The greater part of the beds here, as in the south, lie, however, in an almost horizontal attitude.

Structure is naturally more evident, if not more pronounced, in the Cordillera than in either the central plain or the Laurentian Plateau portions of the basin. The Rocky mountains, which extend northward along the western edge of the basin as far as the Liard river, are built up of sedimentary rocks that have been elevated by pressure exerted from the west into a series of parallel ridges which strike about north 30 degrees west. These ridges are made up of closely folded and faulted beds sometimes thrust one over the other, and dipping at high angles generally towards the west. Nearer the central plain in the foothills, the beds are not so closely compressed and the pressure has produced more open folds with lower dips, but with, however, the same general strike.

The Rocky mountains die out in the latitude of Liard river and that stream flows around their northern extremity, cutting through only a few of the more persistent ridges. The beds are here not so compressed and the structure of the ridges is anticlinal.

In Mackenzie mountains "the structure is characterized by folding, generally on a broad scale, which has thrown the strata into a series of anticlines and synclines; but the folding is sometimes close, and in certain cases the folds appear to be overturned and overthrust."<sup>2</sup> The general strike of the beds in these mountains as far north as latitude 65 degrees north is slightly west of north, but at

<sup>1</sup> Geol. Surv., Can., Ann. Rept., vol. V, pt. I, p. 44 D.

<sup>2</sup> Keele, J., "A reconnaissance across the Mackenzie mountains," Geol. Surv., Can., 1910.



that latitude the trend of the ranges changes and they swing in a wide circle to the westward round the upper branches of Peel river. On Wind river the mountain-building forces have been less intense and the structure is characterized by open folds with comparatively low dips to the beds. The strike of the ranges is here east and west.

Richardson mountains, which separate Peel river from the Porcupine, have a north and south trend. They have on the whole an anticlinal structure, and are broken by longitudinal faults. On the eastern side they present a steep fault face to the delta of the Mackenzie, and the beds undulate gently. In the middle of the range the dips increase to 70 degrees but maintain an easterly direction, and on the western side the beds gradually flatten and finally dip westward. As the range approaches the sea-coast the strike of the beds assumes a more westerly trend.

## ECONOMIC GEOLOGY

### BITUMINOUS SANDS

#### *General Description*

An immense body of bituminous sands, the so-called tar sands, is exposed on Athabaska river. It extends from near Boiler rapid, about 200 miles below Athabaska, to a point many miles below McMurray. Outcrops occur also in the banks of the rivers, and small streams tributary to the Athabaska between these points.

The bituminous sands vary in colour from grey to dark brown or jet black, according to the quantity of contained bitumen and depth of weathering. Where they are heavily saturated they are much softened by the heat of summer, and the bitumen issues from the sands and forms pools. It is believed that they consisted originally of unconsolidated sands and soft sandstone ranging in texture from a fine silt to a coarse grit, and induration has been effected by impregnation with bitumen. The formation contains occasional lenticular beds of ironstone and quartzite and thin seams of lignite. The lower part of nearly all exposed sections consists of unstratified sands and the resulting bituminous sands are fairly homogeneous (Plate XII A). "In passing upward, however, narrow bands of sandstones and occasional quartzites are found interbedded with the originally uncompacted sands (Plate XII B). These non-bituminous strata gradually increase until by their preponderance they entirely replace the bituminous sands."<sup>1</sup> The formation is overlain by the Clearwater shales, from the first exposure at Boiler rapid down to McMurray. It constitutes the basal member of the horizontally disposed Cretaceous series in this region, and rests directly on the Devonian limestone with very little unconformity to mark the great lapse of time intervening between the deposition of the two. The bitumen with which it is impregnated is believed by many to have had its origin in the Devonian formation.

"Other occurrences in the province of Alberta have been recognized near Bonnie Glen (N.W.  $\frac{1}{2}$  sec. 14, tp. 47, range 27, W. 4th mer.); Nakamun (N.E.  $\frac{1}{4}$

<sup>1</sup> Ells, S. C., "Preliminary report on the bituminous sands of northern Alberta," p. 6.

sec. 28, tp. 56, range 2, W. 5th mer.); Legal (secs. 28 and 32, tp. 57, range 25, W. 4th mer.); Westlock (S.E.  $\frac{1}{4}$  sec. 5, tp. 60, range 26, W. 4th mer.); and elsewhere. At none of these localities has bituminous sand been found in commercial quantity, although it is only fair to say that as yet no systematic prospecting has been seriously undertaken. The deposits are, however, so situated that no great outlay would be required to finally determine their commercial value."<sup>1</sup> Bituminous sands are also reported to occur on Wabiskaw river at Prairie river. Fragments of bituminous sand are found at the Upper narrows on Buffalo lake, Saskatchewan. On the east side only small fragments were found; they are low grade and evidently much altered by water action. On the west side bituminous sand occurs as large masses of float, the largest weighing possibly 5 to 8 tons. The beds from which these were derived were not found.<sup>2</sup>

S. C. Ells, of the Mines Branch, Department of Mines, Ottawa, has carried on investigations of the bituminous sands of the Athabaska River section with a view to ascertaining their adaptability to commercial ends.<sup>3</sup> The following information has been abstracted from his preliminary report.

"Although the area represented by actual outcrops has not been accurately determined, it is probably not less than 750 square miles. Extensions of the deposit under heavy cover, particularly to the south, will greatly increase this estimated area.

"At various points wide variations occur in the quality of the material, the thickness and character of the deposits, and, in those topographical and geographical conditions which must, to a large extent, control possible future development."

Measurements were made of a great number of outcrops, but in many instances, earth slides, the growth of timber along the upper part of an exposure, and the presence of talus at the foot of the slope partly obscured the outcrop, so that only approximations were made of the thickness of the formation and of the covering. It was possible, however, to eliminate many outcrops from further consideration on account of the depth of the overburden, the low bitumen content of the deposit, variability in the bitumen content, variability in the mineral aggregate, or difficulties in transportation. The estimated thickness of the bituminous beds and the overburden, and the conclusions arrived at are based wholly on surface indications. Extensive stripping and other systematic exploration would doubtless modify to a certain extent the figures and conclusions.

### *Detailed Description*

Between Boiler rapid and Cascade rapid "bituminous sands are probably more or less continuous along both sides of the river, though the actual outcrop is frequently obscured. Such exposures as do occur are usually much banded, and much of the bituminous sand itself is of low grade." There is also a great thickness of overburden.

Between Cascade rapid and McMurray examination was made of a number of sections exposed at bends in the river. It is probable that beds of workable size and of commercial quality occur in all these sections, but the overburden

<sup>1</sup>Ells, S. C., "Preliminary report on the bituminous sands of northern Alberta," p. 3, footnote.

<sup>2</sup>Ells, S. C., Mines Branch, Dept. of Mines, Can., Sum. Rept., 1914, p. 64.

<sup>3</sup>Ells, S. C., "Preliminary report on the bituminous sands of northern Alberta."

is great. Systematic exploration of the areas of less abrupt topography, lying between the exposed sections, may reveal commercial deposits, but such exploration would be expensive. "Therefore, in view of the more favourable conditions under which bituminous sand is found elsewhere in the McMurray district, it is doubtful if, with one or two possible exceptions, the deposits referred to in Section No. 1 (between Boiler rapid and McMurray), should be seriously considered at the present time."

Along the Athabaska, north of McMurray, thirteen of the more promising outcrops were examined in some detail. "Although all are outcrops of what is apparently one continuous deposit, there is, as elsewhere, considerable variation in quality of material, and mode of occurrence. Consequently it is probable that of the thirteen outcrops examined, quite 50 per cent may, for the present, be eliminated from further consideration. The table on page 90 indicates measurements of representative sections, and requires no comment."

*Principal Exposures, Section 2. Athabaska River, North of McMurray*

Number	Average exposed thickness of high grade	Average exposed thickness of low grade	Total exposed thickness bituminous sand	Overburden	Horizontal distance from outcrop to point at which thickness of overburden is estimated	Lower limit of bituminous sand above or below water level	Side of river	Approximate length of exposure	Miles north of Forks	Remarks
12 (a)	65		65	115	425	Above	E.	4,980	2	Between Poplar island and McMurray, a, b, c, are equidistant sections along outcrop. It is difficult to estimate the thickness of commercial grade sand. The deposit is largely made up of impure partings of clay, etc., which to a great extent destroy its value. Opposite north end Big Poplar island. Bituminous sand is mostly of low grade and much banded. From surface indications, the greater part of it is of no value.
(b)	30		30	165	570	"	"	4,980	3	
(c)			60	170	440	"	"	4,980	3	
13 (a)			90	109+	315	"	"	3,400	6	
(b)	30		30+	180	250	"	"	3,400	6	
(c)	40		40+	145	330	"	"	3,400	6	
(d)	60		60+	90	345	"	"	3,400	6	
14			80	110	520	"	"	600	11	Opposite Stony island the exposed part of this outcrop shows many impure partings. The lower part of this section may contain high-grade material, but is obscured by talus pile 130 feet up the face. On surface indications this outcrop is of no value. This exposure is largely covered by talus and drift, and the average content in bituminous sand apparently does not exceed 5 per cent. One and a half miles below lower Twin islands. Surface indications at sections a and b show a low-grade deposit of very little value. Surface indications show material of low grade and of little value. Surface indications indicate this to be of no commercial value. Much of this exposure is obscured by talus and drift. Surface indications are promising.
15			75	70+	625	"	"	3,000	12	
16 (a)			90	160	700	10ft. above	W.	1,775	16	Material shows numerous partings of clays, etc., and surface indications do not indicate deposit of commercial value. Surface indications promising. Overburden light. Outcrop highly banded with interbedded impurities and is of little apparent value. North of Pierre au Calumet creek. Highly banded. Surface indications indicate low-grade material of little value. Some interstratified partings, but surface indications promising.
(b)			50	205	575	"	"	1,775	16	
17			35	15	125	5ft. above	E.	250+	24	
18			30	70+	250	?	"	1,225	37	
19 (a)	20		65	75	315	?	"	1,225	37½	
(b)	30		60	55	545	?	"	1,225	37½	
20			30	60+	.....	?	"	1,800	38	
21 (a)	14		14	7	450	Sand.	"	900+	40	
(b)	16		16	5-8	450	Above.	"	900+	40	
22			35	50+	350	At.	"	180+	51½	
23			20	23	1,010	Below.	"	500	53	
24 (a)			30	65	1,225	Below.	"	1,200	57½	
(b)			35	110	1,575	Below.	"	1,200	57½	
25		45	45+	60	950	?	"	600+	19	
26			60	5-15	200	.....	W.	5,000	52	
27			70	10-20	300	.....	"	500+	36	

Outcrops of bituminous sands occur in the lower courses of many of the tributaries of the Athabaska. Difficulties of transportation would, however, militate against the development of numbers of these.

On Horse creek, in the lower  $5\frac{1}{2}$  miles of the valley, exposures are seen that indicate the presence of a very large tonnage. "Much of this, judged by material seen in outcrops, and apart from grading of mineral aggregate, is of commercial grade; but probably not more than four or five outcrops are so situated as to permit of practical development. The areal extent even of these, is limited by the narrow and precipitous nature of the valley."

There are difficulties in the way of transportation. "At alternate bends in the stream, where the current impinges against the banks, the possibility of heavy clay slides must be taken into consideration. Points opposite such cut banks are, however, usually low and free from the effects of slides."

On Clearwater river, which flows through a larger valley than the Athabaska, only one exposure is seen for 20 miles above the mouth, although there is little doubt that the bituminous sands extend many miles up the river and are obscured by drift and forest growth. The outcrop occurs on the north shore a quarter of a mile west of the mouth of Hangingstone creek. The maximum thickness exposed is 20 feet, and the bitumen content and the grading of the mineral aggregate vary greatly.

On Hangingstone creek, which occupies a deep, notch-like valley, there are outcrops at nearly every bend along the first 5 miles. It may be that by careful exploration some points will be found at which quarrying operations can be carried on successfully.

On Christina river, twenty-four exposures were noted, but measurements were made of only seven, the others being eliminated owing to heavy overburden, prevalence of clay slides, and the presence of impure partings in the bituminous sand itself. The depth of the overburden would be a serious handicap in the development of deposits along this river. "Topographically, the valley of the Christina river resembles that of Horse creek. Its course is, however, more direct and the small areas of bottom lands are consequently fewer. . . . . it is probable that better grades and a better alignment can be secured than on either Hangingstone or Horse creeks. Owing, however, to the unstable and often precipitous character of the banks, it is very doubtful if, even here, a surface line could be maintained within the valley itself."

On Steepbank river, which enters the Athabaska  $21\frac{1}{2}$  miles below McMurray, a number of promising outcrops occur. Details are given in the following table concerning nine of the more promising outcrops of the twenty-six seen.

"Based on surface indications, the deposits of bituminous sand on Steepbank river may be considered quite as promising as those seen on any other stream in the McMurray district. Owing to the sandy and gravelly character of much of the overburden, there is a general absence of the heavy clay slides so frequently met with on some of the other streams. Such a consideration is of importance in considering possible development and transportation within a narrow valley."

*Principal Exposures along Steepbank River*

Number	Average exposed thickness, high grade	Average exposed thickness, low grade	Total average exposed thickness, bituminous sand	Overburden	Horizontal distance from water's edge to point at which thickness of overburden is estimated	Lower limit of bituminous sand	Side of river	Approximate length of outcrop	Distance from mouth of river
54	.....	.....	90	15-20	300	20 feet-40 feet above water level.	N.E.	400	Miles 2
55 (a)	.....	.....	160	20	250	15 feet-20 feet above	S.W.	800	2
(b)	.....	.....	180	15	250	.....	S.W.	800	2
56	70	100	170	25	300	At.	N.E.	275	3
57	.....	.....	30-70	10-90	325	10 feet above.	S.W.	625	3½
58	70	80	150	40	300	Near.	S.W.	200	5
59	75	80	155	20	300	Near.	N.E.	300+	5½
60	12	.....	12	8	200	Below.	S.W.	300	5½
61	75	60	135	20	250	Below.	N.E.	500	10
62	.....	.....	120	25	300	Below.	S.W.	425	12

Shows much banding due to narrow partings of clay, etc.  
 Outcrop shows much banding and does not appear so favourable as others farther up river.  
 Low grade is highly banded, but high grade is of good quality.  
 Material good and conditions relatively favourable.

Outcrop shows much banding.

On Muskeg river occasional small deposits of bituminous sands occur, but surface features do not indicate that any of these are of commercial value. Only low-grade deposits were observed on Pierre au Calumet creek, and none of commercial importance on Firebag river. Exposures occur on Calumet river, but appear to be of no commercial importance, and those seen on Tar river are low grade and of a highly banded character.

A number of outcrops occur on Moose river, which enters the Athabaska from the west 47 miles below McMurray, and some of those seen between 4 and 8 miles up stream are of sufficient promise to warrant further detailed exploration. "The valley of the Moose is for the most part narrow, with banks rising 150-200 feet. At a number of points, however, changes in the course of the river have resulted in the formation of occasional lateral basins and low-lying areas, which may prove of importance should development of the bituminous sands be undertaken here . . . . . As on other streams of a similar character transportation within the valley itself will present difficulties. Owing, however, to light overburden causing fewer clay slides, the maintenance of a line would not be so difficult as on most of the other tributaries of the Athabaska river."

On MacKay river sections of the bituminous sands were seen along the lower 22 miles of its course. Nine were examined in detail; these lie at distances of  $\frac{3}{4}$ , 2,  $2\frac{1}{2}$ ,  $7\frac{1}{2}$ , 8, 9, 10, 12, and 13 miles from the mouth of the river. Surface indications lead one to suppose that some of these are of commercial value. "The river flows through a narrow valley, marked by precipitous slopes and high cut banks" and difficulties of transportation would be encountered.

#### *Utilization*

*Extraction of Bitumen from Bituminous Sands and Sandstones.* "At various localities in the United States during the past twenty years, the commercial extraction of bitumen from bituminous sands and sandstones and from bituminous limestones has been attempted" and many hundreds of thousands of dollars have been spent in the construction of plants for this purpose.

"Generally speaking, commercial extraction in the past has been attempted by the use of solvents—principally carbon disulphide, and the lighter petroleum distillates—and by the use of hot water and steam. Of the first two solvents, carbon disulphide is more expensive and more volatile, while the escaping fumes are a menace to the health of employees. In actual commercial practice, however, it appears that neither the use of naphtha nor of carbon disulphide has been successful. Apart from attendant danger from fire and explosions, there is a serious loss in the solvent employed. Such a loss, due in part to evaporation and in part to failure to fully recover the solvent from the extracted bitumen and from the sand tailings will, at times, probably aggregate nearly 15 per cent.

"The results when hot water and steam have been used have been more encouraging. A fairly rapid and inexpensive separation has been possible, but in actual commercial practice the extraction has not been sufficiently complete. Summarizing all evidence available to the writer, it appears that, as at present understood, the use of hot water or steam, or a combination of the two, will not give a commercial extraction of more than 60 per cent of the bitumen contained in average bituminous sand-rock. In attempting to secure a higher percentage of extraction, a disproportionate increase in cost will probably result."

In conclusion Ells says:

"It is thus safe to say that, even apart from the actual merits of any of the processes that have been used, the extraction of bitumen from bituminous sand-rock has not met with commercial success. Nevertheless, in view of the various factors that must be taken into account in considering past attempts, it is difficult to say whether, under the most favourable conditions, commercial extraction may or may not be feasible. Meanwhile, those who may care to attempt extraction on a commercial scale and under conditions prevailing in northern Alberta, will have available the results of many years' elaborate and often costly experimentation, on which to base their efforts. Further, it should be remembered that, owing to freight and other charges on imported asphalts, extraction in Alberta would be on a more favourable basis than has, for example, been the case in California, where competing residuum can be sold at a very low figure."

*Material for Road Construction.* The applicability of bituminous sands to road construction is dependent on the character of the mineral aggregate, and the proportion and character of the contained bitumen.

Examinations have been made of the grading of the sand in a number of samples and it has been found that in this respect much of the Alberta material is unsatisfactory. "It is, however, possible that a further and more detailed investigation of individual deposits will show that a combination of material from two or more localities will result in a satisfactory grading of the aggregate."

"In general, the per cent of asphalt cement required in various classes of bituminous road construction ranges from 6 to 12. The average per cent of bitumen contained in samples of Alberta bituminous sand examined is about 15. Of this amount 15-17 per cent will be lost in necessary preliminary heating. On such a basis the bituminous content actually available in the anhydrous sand will thus be reduced to 12-13 per cent." Some difficulty would be encountered in reducing the proportion of bitumen by the addition of sand. "If, however, the mixer used be furnished with sufficient power and the sand itself be preheated the desired reduction could doubtless be effected.....it appears that specially designed machines will have to be constructed before Athabaska bituminous sand can be seriously considered as a paving material....."

"Before it can be successfully adapted to sheet asphalt work, the bitumen contained in the Alberta sand will require a very considerable modification. The penetration of the extracted bitumen is much too high and constitutes the dominant feature in considering its value as an asphalt cement. In the laboratory this feature can be sufficiently modified by proper heating and fluxing. Whether this will be found practicable when undertaken under conditions governing actual paving construction, can best be determined under conditions more nearly approaching those of commercial work."

The "Preliminary report on the bituminous sands of northern Alberta," from which the foregoing information has been abstracted, contains detailed information regarding about eighty different outcrops, analyses, hints on prospecting, and other information of practical value.

During the summer of 1915 some experiments<sup>1</sup> were conducted under the supervision of S. C. Ells of the Mines Branch, in the practical application of the bituminous sands in street construction in the city of Edmonton.

<sup>1</sup> Mines Branch, Dept. of Mines, Can., Sum. Rept., 1915, pp. 67-74.



"As a site for this pavement, a section of Kinnaird street, immediately south of Alberta avenue, was selected. The traffic along this part of Kinnaird street is such as will give a pavement a fairly severe test and may be classed as heavy. Apart from a considerable volume of fast automobile travel, it includes vehicles which carry loads up to eight and ten tons."

The shipment for this test consisted of bituminous sands of both coarse and fine mineral aggregates. Modifications were necessary to correct such features as high penetration of asphalt cement, unbalanced mineral aggregates, and excess of asphalt cement (15 per cent).

<sup>14</sup>"The effect of unduly high penetrations was modified by partial distillation of the more volatile fractions. The unbalanced aggregates of coarse and fine bituminous sand were partially corrected by combining the two in a proportion of two of fine to one of coarse. In the case of the sheet asphalt mix, the resulting aggregate was further modified by the addition of clean and graded sand; in the case of the bitulithic mix, by the addition of clean sand and graded, crushed gravel. In the case of the bituminous concrete, fine-grained bituminous sand only was used, and was modified by the addition of graded crushed gravel and of clean sand. This manipulation also reduced the somewhat high percentage of asphalt cement present in the original material to the final percentage desired in each case."

The pavement was opened to traffic on August 26, 1915. Under date of November 1, 1916, A. W. Haddow, Acting City Engineer of Edmonton, reported to Eugene Haanel, Director of the Mines Branch, as follows:

"I have your letter of October 24, inquiring as to the condition of the experimental pavement which you laid in this city with the native bituminous sands from Fort McMurray and Fort MacKay. I examined this pavement again yesterday on receipt of your letter, and find it in perfect condition. The only defect is the transverse crack which is probably due to contraction of the base and subgrade, and could not be taken in any way as default of the surfacing.

"The pavement does not show any markings due to horse traffic in hot weather. There are no indications of any waving either in the sand mixture or rock mixture. There is no indication of any pitting, which we sometimes find in our suburban roads, due to the clay caking on the surface, and when it flakes off, very often pits the surface by taking a small portion with it."

Mr. Ells is of the opinion that with minor modifications in the manipulation adopted in connexion with the experimental paving referred to above, Alberta bituminous sand can be successfully used as a basis for satisfactory asphaltic pavements.

"From a comparative study of cost data, based on the use of Alberta bituminous sand and of imported asphalts, it appears that the application of the former in the crude state will be restricted within comparatively narrow limits in western Canada. Indeed, extensive development of the McMurray deposits will probably depend on the commercial application of an extraction process whereby the bitumen can be marketed in a more or less pure form. Such a process would doubtless ensure for the McMurray product a wide market, not only as a paving material, but in many other recognized applications for high grade bitumen."

Topographic maps embracing many of the most important deposits have been published by the Mines Branch, Department of Mines, Ottawa, on a scale of 1,000 feet to 1 inch and with contour intervals of 20 feet.

<sup>1</sup> Ells, S. C., *Can. Min. Jour.*, vol. XXXVII, No. 3, pp. 73-74, Feb. 1, 1916.  
15850-7½

## CLAYS

Investigations have been made of some of the clay deposits on Athabaska river and its tributaries, and of some of the clays and shales along the line of the Grand Trunk Pacific railway.

In the Athabaska district the clays examined immediately overlie the Devonian limestone or are associated with the McMurray sands. "An excessive percentage of carbon is noted in the case of certain of the samples examined. Where the clay lies between the bituminous sand and the Devonian limestone, this contained carbon has been largely, if not altogether, derived from the overlying bituminous sand. It is probable that such contamination would materially decrease on working in from the outcrop." The depth of the overburden, and transportation difficulties are matters for serious consideration. Results of laboratory tests of some of the more important clays are extracted from a report published by the Mines Branch, Department of Mines, Canada, and entitled "Notes on clay deposits near McMurray, Alberta," by S. C. Ellis.

"*Laboratory No. 190.* From point on northwest shore of Muskeg river, between head of portage and mouth of river.

"A light grey, very plastic clay, with good working and drying qualities. It burns to a cream-coloured, dense, steel-hard body at cone 3, with a total shrinkage of 9 per cent, and softens when heated up to a temperature of cone 27. This is a good example of a stoneware clay, and is also a fire-clay. It is the most refractory clay at present known to occur in the province of Alberta. . . .

"*Laboratory No. 310.* This clay requires 23 per cent of water to bring it to the best working consistency. It is very plastic, and smooth. The drying must be done slowly after moulding, to avoid cracking. The drying shrinkage is about 7 per cent. The results obtained in burning are as follows:

Cone	Fire shrinkage	Absorption	Colour
	%	%	
010	0	10	buff
06	1.4	8	"
03	3.0	3	"
1	3.4	2	dark buff
5	2.0	0	grey
15	Fused.		

"This is one of the better grades of clay, with good working qualities, and shrinkages within commercial limits. It would be suitable for the manufacture of hard burned fireproofing buff face bricks, or sewer-pipe. The drying qualities could be improved by the addition of a small percentage of ground-burned clay to the raw clay. It must be burned slowly." This sample was taken on MacKay river, 11.2 miles from the mouth.

Samples 191, 313, 314, and 317 were taken along Moose river at distances of 3.3, 6.75, 6.7, and 1.8 miles respectively from the mouth. The deposits are greatly concealed by slides and talus.

"*Laboratory No. 191.* From Moose river, interbedded between bituminous sand and Devonian limestone.

"Dark grey, very plastic, smooth, fine-grained clay of the stoneware type. Burns to a salmon-coloured dense body at cone 3, with rather high shrinkage, and fuses at cone 15.

"*Laboratory No. 313.* This clay only required 14 per cent of water for tempering, owing to the presence of a large percentage of rather fine-grained quartz sand. The plasticity and working qualities were low for this reason.

"The drying shrinkage was only 3 per cent.

"The following results were obtained on burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	0	8	salmon
06	0	8	buff
03	0	8	"
5	0	7	"
14	begins to soften		grey
18	fused		

"As this clay is too sandy to use alone, a mixture was made by adding 50 per cent of a fat clay (315) from a nearby locality. This gave a body with properties intermediate between the two extremes of a highly plastic clay with large shrinkage, and a lean clay with low shrinkage, so that the results obtained in working and burning were good. The air shrinkage was about 5 per cent. A steel-hard, practically non-absorbent body was produced at cone 1.

"This mixture would probably be suitable for sewer-pipe, or electrical conduits.

"*Laboratory No. 314.* This is a soft, grey clay, with good plasticity and working qualities. Wares moulded from it will stand fast drying without checking.

"The drying shrinkage is 6 per cent.

"The following data were obtained on burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	0	12	salmon
06	1.0	9	"
03	2.3	6	"
1	3.4	1	buff
5	4.6	0	grey
9	intact		
14	softens		

"This is a good material, the shrinkages are low, and it gives no trouble on burning. It would be useful for the manufacture of face brick, fire-proofing, electrical conduits or sewer-pipe.....

"*Laboratory No. 317.* Light grey clay, with slightly reddish tinge, requiring only 17 per cent of water for tempering. It is rather stiff in working when wet; the plasticity is good, and the clay is very smooth. The drying qualities were not tested, but they are probably good, owing to the small amount of water required to bring it to a working condition.

"The drying shrinkage is 5 per cent, and the following results were obtained on burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	0	10	salmon
06	0	10	"
03	1	7	buff
1	1	6	"
5	2	3	grey
9	4	vitrified	"
16	fused.		

"This is a stoneware clay suitable for the manufacture of pottery, crocks, jars, teapots, etc. It would require some experimental work to fit the bodies with suitable glazes, but it is probable that the usual Bristol and slip glazes used for stoneware articles would answer.

"Some 3-inch, round, hollow tile, was made on a hand press, and sent to a commercial sewer-pipe plant for a salt-glazing test.

"*Salt-Glazing Test.* The results of the salt-glaze tests on this clay show that the glaze cannot be successfully applied at cone 3, as that temperature is too low. The body showed no sign of vitrification, being still porous and rather soft.

"It would require a temperature in the kiln of at least cone 5, or better, at cone 6, to produce a glaze on this clay. It will then show a glaze equal to number 315, but of lighter colour. The commercial kiln in which the tests were made did not give a higher temperature than cone 3, hence it was impossible to complete the test on this clay.....

"Laboratory Nos. 319 and 320, are from the point near which the southerly boundary of the Murphy bituminous-sand claim meets the east shore of the Athabaska river. Owing to slide and talus, the thickness of the clay would not readily be accurately determined, but appears to be quite 20 feet. At the points from which the samples were taken the overburden appears to consist of from 10 to 20 feet of low-grade bituminous sand. What appear to be extensions of the same bed reappear along the river at intervals for one-third of a mile to the south of the point where samples were secured.

"*Laboratory No. 319.* A light grey, highly plastic, and smooth clay, with good working properties. It must be dried slowly, being liable to check if dried too fast. The drying shrinkage is 5.5 per cent.

"The following results were obtained on burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	0	11	salmon
06	0	10	"
03	0.6	8	buff
1	1.3	6	"
5	2.0	5	grey
17	4.0	vitrified	"
17	fused		

"This is a typical stoneware clay, suitable for the manufacture of all classes of stoneware articles, and pottery.

"It is not a fire-clay, but may be sufficiently refractory for stove linings, boiler-setting blocks, or other purposes where extremely high temperatures would not be used.

"This is one of the best clays of the series; it closely resembles No. 317, which is almost as good. It is not so refractory as No. 190, which stands up at the highest temperature of any of these clays."

Tests have been made of shales and clays occurring along the line of the Grand Trunk Pacific railway in the vicinity of coal seams west of Edmonton and some of these have been found suitable for common brick, fireproofing, and field drain tile. The results of the tests are published by the Geological Survey, Ottawa, in memoirs written by Heinrich Ries and Joseph Keele.

Ries says that "one of the most promising areas in which to prospect for shales to be used in the manufacture of clay products is in the Jasper Park region.

Here, on the south side of the river, several coal seams have been opened up, and associated with them, so far as known, are carbonaceous, sandy shales, which do not appear very promising, but the section cannot be said to have been fully explored, so that other shales in these Cretaceous beds may be developed later.”<sup>1</sup>

## COAL

Coal is one of the most important mineral resources of the Mackenzie basin. It occurs in the Cretaceous formations of the southern part of the basin and in the Tertiary formations of the northern part. Mining operations are being conducted on important seams in the Cretaceous rocks along the Grand Trunk Pacific railway, and descriptions of these are found in the publications of the Geological Survey. In this report, however, descriptions will be given of only the more remote and less known seams, which lie farther north.

In the foothills north of the Grand Trunk Pacific railway a coal field extends from tp. 49, range 27, W. 5th mer., northwestward to tp. 59, ranges 7, 8, and 9, W. 6th mer., and beyond. The seams occur in the Kootenay formation. The coal is high-grade bituminous and at least one seam on Smoky river may be classed as anthracite. Exposures occur on Hay river, Smoky river, Sheep creek, and other streams.<sup>2</sup> MacVicar gives analyses of samples taken from a number of seams in different parts of the field. Those from the Isenberg claim, Smoky river, tp. 58, range 8, W. 6th mer., serve to illustrate the range of composition of coals from this field.

*Analyses of Coals from Isenberg Claim, Smoky River*

Thickness of seam, feet	Moisture	Volatile matter	Fixed carbon	Ash	B.T.U.
8	0.5	19.6	63.4	16.5	12715
9	0.4	21.1	69.8	8.2	14040
17	1.1	18.4	74.0	6.5	14100
12	0.4	18.5	69.4	11.7	13600
9	0.3	19.8	73.0	6.9	15070
7½	1.3	12.5	78.2	8.0	13862
7	0.9	13.4	81.7	4.0	14706
7	2.9	14.8	80.1	2.2	13800
10	1.7	18.1	73.9	6.3	13990
15	1.6	19.4	71.6	7.3	13255
5	0.9	14.7	82.5	1.9	14987
10	0.7	22.6	72.3	4.4	14800
7½	0.5	18.5	72.8	8.2	14300
10	0.7	15.3	76.2	7.8	13913
13	0.5	18.4	73.5	7.6	14220
9	1.0	20.3	71.9	6.7	14160

Lignite seams 2 or 3 feet thick are found in the McMurray sandstone and a seam 4 feet thick occurs in this formation on Christina river 5 miles above its mouth.<sup>3</sup> Seams of lignite, varying from a few inches to 5 feet in thickness, are exposed at intervals also through the Grand Rapids sandstone on the Athabaska. The quality of the coal, however, is usually inferior.<sup>4</sup> A seam lying just above the

<sup>1</sup> Geol. Surv., Can., Mem. 47, 1914, p. 42.

<sup>2</sup> Geol. Surv., Can., Sum. Rept., 1916.

<sup>3</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 39 D.

<sup>4</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 29 D.

Grand Rapids sandstone outcrops at various points through a distance of 15 miles on both sides of the Athabaska, above and below Grand Rapids. The seam is 3 to 15 feet thick, but carries numerous clay partings. There are thin bands of fairly clean lignite from 1 to 2½ feet thick.<sup>1</sup>

The Bull Head Mountain formation of the Peace River district is coal-bearing. A great many seams are exposed in the canyon a few miles above Hudson Hope, and in the small streams of the vicinity, but only a few exceed 3 feet in thickness.<sup>2</sup>

The formation has been tilted by the uplift forming the mountain around the end of which the river swings at this point, so that to the south and southwest of the mountain the strata dip southwesterly at angles of 10 to 25 degrees. In spite of this uplift the strata are remarkably free from disturbance, with the exception of a fault on Gething creek and a few minor folds.

In Peace River canyon a great number of small seams occur, but only three were seen to be over 2 feet thick. Of these P1<sup>3</sup> measures 2 feet 11 inches, possesses a strong roof and floor, and is of superior quality.

On Gething creek, twelve seams were observed, of which only five are over 2 feet thick and only one, G12, over 3 feet.

*Section of G12.*

Sandstone roof	Feet	Inches
Shale . . . . .	0	7
Coal (dull) . . . . .	1	4
Coal (bright) . . . . .	1	4
Parting (shale) . . . . .	0	1
Coal (bright) . . . . .	1	0
Sandstone floor.		

A seam, which is probably G12, is seen from a point opposite the islands in the cliff on the south side of Peace River canyon for a distance of nearly 2 miles. The analyses from G12 show it to be of superior quality.

*Section of M1 and M2 on Moose Bar Creek.*

Sandstone roof	Feet	Inches	
Shale . . . . .	1	0	
Coal (dull) . . . . .	0	9	} M1
Shale . . . . .	0	7	
Coal (dull) . . . . .	0	3	
Sandstone . . . . .	1	7	
Coal . . . . .	0	1	
Sandstone . . . . .	0	3	
Coal . . . . .	0	2	
Shale . . . . .	2	7	
Coal (bright) . . . . .	1	1½	} M2
Sandstone . . . . .	0	½	
Coal (bright) . . . . .	1	6	
Shale . . . . .	0	3	
Coal (bright) . . . . .	0	1	
Hard shale floor.			

On Johnson creek twenty seams are exposed, but only four exceed 2 feet in thickness and three exceed 3 feet.

<sup>1</sup>Ells, S. C., Mines Branch, Dept. of Mines, Can., Sum. Rept., 1914, p. 65.

<sup>2</sup>Galloway, C. F. J., Ann. Rept., Minister of Mines, B.C., 1912, pp. 118-136.

<sup>3</sup>Mr. Galloway's numbering of the seams is retained.

*Section of J12 and J13.*

	Feet	Inches	
Shaly sandstone.			
Shale.. . . . .	1	0	
Coal (dull).. . . . .	0	10	} J12
Shale.. . . . .	1	0	
Sandstone.. . . . .	0	2	
Coal (dull).. . . . .	0	6	
Shale.. . . . .	2	6	
Coal (bright).. . . . .	2	0	} J13
Shale.. . . . .	0	2	
Coal (bright).. . . . .	1	3	
Sandstone.. . . . .	0	1	

Shale floor.

*Section of J14.*

Sandstone.			
Grey shale.. . . . .	1	6	
Hard shale.. . . . .	0	2	
White sandstone.. . . . .	0	4	
Hard, grey shale.. . . . .	1	6	
Coal.. . . . .	1	8	
Sandstone.. . . . .	0	2	to
Coal.. . . . .	2	3	

Sandstone floor.

*Section of J15 and J16.*

	Feet	Inches	
Sandstone.			
Coal.....	1	3	} J15
Sandstone.. . . . .	1	6	
Shale.. . . . .	3	0	
Coal (hard).. . . . .	2	6	} J16
Shale.. . . . .	0	1	
Coal.. . . . .	0	2	
Shale.. . . . .	1	0	
Coal.. . . . .	0	8	

Shaly sandstone floor.

*Section of J20.*

	Feet	Inches
Sandstone roof.		
Coal.....	2	3
Coal.....	0	6
Shale.....	4 in. to	1

Sandstone floor.

It is possible J13 and J14 are identical and correspond to M2. "The sections of J13 and M2 are very similar, each having a small rider of dull coal above it, and the correspondence of these two is highly probable. In the case of J14, however, the similarity is much less, and its analysis would almost exclude the possibility of its being correlated with M2. Unfortunately no samples were taken of J13. . . . ."

"In cases where a seam is visible over a considerable distance, the thicknesses of the individual benches of coal and shale are variable, the shale sandstone partings in the seams being frequently of a lenticular nature, increasing within a distance of a few feet from 1 inch to over 1 foot in thickness, and diminishing again as rapidly. The sections given represent, as nearly as could be observed, average conditions".<sup>1</sup>

Coal seams are also reported as outcropping on Eightmile creek 7 or 8 miles from its mouth.

<sup>1</sup> Galloway, C. F. J., Ann. Rept., Minister of Mines, B.C., 1912, p. 133.

Analyses of Peace River Coals<sup>1</sup>

Seam	Thick-ness		Hygro. water	Vol. comb. mat.	Fixed carb n	Ash	Coking quality	Split vol. ratio
	Ft.	In.						
G12, top bench (dull coal).	1	4	2.9	15.6	79.4	2.1	None	8.15
G12, lower benches.....	2	2	2.8	16.9	77.2	3.1	"	7.61
M1 (dull coal).....	0	10	1.0	14.5	70.6	13.0	"	9.43
M2, top bench.....	1	1½	3.0	18.0	73.6	5.4	"	6.88
M2, lower bench.....	1	7	1.7	16.3	53.7	28.3	"	6.28
J14, top bench.....	1	8	2.7	20.9	67.6	8.8	"	5.93
J14, bottom bench.....	2	3	1.8	23.9	67.8	6.5	Fair	5.80
J16, top bench.....	2	8	1.6	15.9	77.4	5.1	None	8.93
J16, bottom bench.....	0	8	1.0	21.4	73.7	3.9	Fair	7.21
J20.....	2	9	1.1	16.0	73.1	9.8	None	8.91
P1 (Section 1).....	2	11	2.2	15.6	80.6	1.6	"	8.84

In the gorge of a small brook entering Pine River South near Table mountain, four seams of bright coal occur in 90 feet of alternating beds of sandstone and shale. These seams in descending order are 6, 8, 24, and 6 inches thick.<sup>2</sup> On the lower part of Coal brook, which flows into the east branch of Pine River South, there are several thin seams, the thickest being 6 inches. Coal also occurs on the east branch of Pine River South. A seam of lignite of inferior quality, 12 inches thick, occurs on Brulé river, near its mouth, about 14 miles below Dunvegan.<sup>3</sup>

F. H. McLearn states that "Lignite occurs in the upper sandstone member of the Peace River sandstone, approximately 25 feet below the top at a point about 10 miles below Peace River. It is also found at a similar horizon near Peace River on Heart river, etc. Owing to the lateral changes in composition and thickness this coal horizon can hardly be considered from the standpoint of large scale operations. However, where locally the coal is of good quality and of sufficient thickness and is of marketable value not far (a few feet) from the face, i.e., all coal removed can be sold, small scale operations may be advisable. A sample of a layer of lignite 7 inches to 1 foot 2 inches thick, underlain by 4½ feet of lignite shale (ash 58.29 per cent) gave the following analysis (Mines Branch, E. Stansfield, Chief Engineering chemist).

	Per cent
Moisture.....	14.2
Ash.....	13.9
Volatile matter.....	28.9
Fixed carbon.....	43.00

"The greatest thickness of clean lignite measured in the cliffs by the writer was 1 foot 6 inches. Marketable coal of greater thickness, however, may be present in places.

"The Dunvegan sandstone cannot be looked upon as a coal producer. A small lignite seam is present in the cliffs below Montagneuse river, but is never thicker than 6 inches."

<sup>1</sup> By H. Carmichael.

<sup>2</sup> Selwyn, Alfred R. C., Geol. Surv., Can., Rept. of Prog., 1875-76, p. 53.

<sup>3</sup> Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1879-80, p. 118 B.



Lignite coal is seen at a number of places in the banks of the Athabaska for 62 miles above Fort Assiniboine and several miles below. About 28 miles above the mouth of McLeod river the following section is found.

	Feet	Inches
Sandstone and shales.. . . . .	..	..
Shaly lignite.. . . . .	3	0
Soft sandstone and shale.. . . . .	4	0
Good lignite.. . . . .	1	8

Two beds occur about 8 miles farther down.<sup>1</sup> "They are shown near the water's edge in a slide detached from the main bank. The upper seam here has a thickness of ten feet, without including in this measurement about six thin, shaly partings, which make up in all about ten inches of shale. Below this seam is about twenty feet of soft, earthy sandstone and shale, followed by a second seam of clean, hard, lignite coal three feet in thickness." G. C. Hoffmann<sup>2</sup> gives the following analyses.

	Ten-foot seam	Three-foot seam
Hygroscopic water . . . . .	11.47	10.58
Volatile combustible matter.. . . .	32.09	32.79
Fixed carbon.. . . . .	47.79	50.19
Ash . . . . .	8.65	6.44

Two thin seams of lignite occur at what is probably the same geological horizon farther down the river.

Fragments of coal were observed on the upper course of Wapiti river and on its tributary, Mountain creek, and thin seams occur in the banks of the latter. Drift lignite is also abundant in Little Smoky river.

Coal occurs on McLeod river and near Wolf creek in tp. 52, range 15, W. 5th mer.<sup>3</sup> Thin seams have been observed on Fort Nelson river and Pine river,<sup>4</sup> and some outcrops occur on Doig river where it crosses the twenty-third base-line.<sup>5</sup> Lignite has also been observed in township 78 along the fifth meridian<sup>6</sup> and there are seams at several horizons in the plateau to the south of Lesser Slave lake.<sup>7</sup> At an elevation of 3,300 feet there are two seams 20 inches and 21 inches thick separated by 8 feet of shale, and 100 feet lower there are other seams the thickest of which is 3 feet. These are exposed along Driftpile river north of the eighteenth base-line and at a number of points along the northwest slope of Inverness valley. Fragments of lignite are found on the lower slopes of Martin mountain and at many other points in the Peace River district. Small seams of impure lignite occur on Liard river, and Coal river, one of its tributaries, brings down fragments of similar material.<sup>8</sup>

In describing the coal deposits of the Peel River basin Camsell states that "Seams of lignite occupy extensive areas in the rocks of the Tertiary basin at the Bonnet Plume river. The largest seam noted was thirty feet in thickness, another was eight feet, and several varied from two inches to ten. The lignite is not of very good quality, and has been burnt in many places by the

<sup>1</sup>Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1879-80, p. 126 B.

<sup>2</sup>Geol. Surv., Can., Rept. of Prog., 1879-80, p. 10 H.

<sup>3</sup>Dowling, D. B., Geol. Surv., Can., Sum. Rept., 1909, p. 149.

<sup>4</sup>Ogilvie, Wm., Top. Surv. Branch, Dept. of the Interior, Ann. Rept., 1892, p. 27.

<sup>5</sup>Akins, J. R., Top. Surv. Branch, Dept. of the Interior, Ann. Rept. 1911-12, p. 58.

<sup>6</sup>Ponton, A. W., Top. Surv. Branch, Dept. of the Interior, 1908-09, p. 170.

<sup>7</sup>Allan, J. A., Geol. Surv., Can., Sum. Rept., 1918, p. 11 C.

<sup>8</sup>McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. IV, p. 41 D.

fires which have been in existence for many years. Lignite also occurs a few miles above the mouth of Cariboo river, and also in the canyon of the Rat river above the mouth of Barrier river. Many sections of the Peel plateau below Snake river show beds of peat resting on the clay or sandstone, sometimes as much as twelve feet in thickness."<sup>1</sup>

The Tertiary beds on the Mackenzie at the mouth of Great Bear river hold several seams of lignite ranging in thickness from 2 to 4 feet,<sup>2</sup> and a seam exceeding 9 feet in thickness was reported by Sir John Richardson as being visible a short distance above Great Bear river, at low water, during the autumn.<sup>3</sup> Drift lignite is also found on the lower part of Gravel river.<sup>4</sup>

Franklin mentions that Garry island at the mouth of the Mackenzie "is terminated to the northwest by a steep cliff, through which protrude, in a highly-inclined position, several layers of wood-coal, similar to that found in the Mackenzie."<sup>5</sup>

R. MacFarlane, in speaking of the Lockhart river below its junction with the Iroquois, says: "The formation of the banks of the Lockhart for some distance after we fell upon it, consisted of a bituminous coal, resting on a bed of limestone with an upper layer of vegetable mould covering a bed of from two to ten feet of clay, underneath which the carboniferous stratum appeared. Lower down, the formation was perceived to be stratified shale."<sup>6</sup>

#### COBALT

No important deposits of cobalt are known to occur in the basin, but the rocks on the east shore of McTavish bay, Great Bear lake, are stained in places with cobalt-bloom,<sup>7</sup> and at one locality on the north shore of the bay west of the narrows between Christie and McLeod bays, Great Slave lake, cobalt-bloom was observed,<sup>8</sup> associated with green copper stains arising from the weathering of thin plates of chalcopyrite in joints in greenstone.

#### COPPER

No important copper deposits are known to occur in the Mackenzie River basin. Native copper has been reported, however, at the northeast end of McTavish bay.<sup>9</sup>

#### GOLD

Gold has not been discovered in any important quantity in the Mackenzie basin east of the Rocky mountains, and the extent of country known to be favourable for prospecting for this metal is quite limited.

<sup>1</sup> Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XVI, p. 47 CC.

<sup>2</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. IV, p. 31 D.

<sup>3</sup> "Arctic searching expedition—a journal of a boat-voyage through Rupert's Land and the Arctic sea in search of the discovery ships under command of Sir John Franklin," 1851, p. 189.

<sup>4</sup> Keele, J., "Reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and Northwest Territories," Geol. Surv., Can., 1910, p. 50.

<sup>5</sup> Franklin, John, "Narrative of a second expedition to the shores of the Polar sea in the years 1825, 1826, and 1827," p. 37.

<sup>6</sup> Can. Rec. of Sc., vol. 4, 1890, p. 32.

<sup>7</sup> Bell, J. M., Geol. Surv., Can., Ann. Rept., vol. XII, p. 27 C.

<sup>8</sup> Bell, Robt., Geol. Surv., Can., Ann. Rept., vol. XII, p. 108 A.

<sup>9</sup> Bell, J. M., Geol. Surv., Can., Ann. Rept., vol. XII, p. 27 C.

Ogilvie, who descended Peace river from Fort St. John to Peace River Crossing in 1891, states that "Gold is found in small quantities on Peace river, and at present there are several miners on that stream."<sup>1</sup> McConnell in describing gold placers on this river says that "Three miles above the mouth of Battle river, a large bar nearly a mile long, on the left bank, was examined, from which we obtained fifteen to twenty colours of fine gold, by washing a few handfuls of the mixed gravel and sand in an ordinary frying-pan. We tried the bar at several points and always with the same result. A small stream descends from the plateau on the opposite side of the river, and by leading its waters across the river, which is here about 1,000 feet wide, the bar might be easily and inexpensively worked on a large scale. Twelve miles farther up the river, another bar was examined, which yielded from twenty to forty colours, when washed in the same way. Numerous other bars occur in this portion of the river, which would probably give as good results as those examined.

"The presence of fine gold in some quantity in the bars above the mouth of Battle river is probably due to the diminution in the strength of the Peace River current which takes place here, and its consequent loss of transporting power. The same fact is shown in the gradual substitution of sand-bars for gravel-bars which occur at the same point.

"Besides the gold on Peace river, two colours were also washed out of a bar on Loon river, an eastern tributary of the Peace."<sup>2</sup> Gold placers have been worked to a limited extent on Braman's flats 25 miles above the canyon of the Peace. Tests made at this place for platinum gave unsatisfactory results, although traces were obtained.<sup>3</sup> Small quantities of gold have been obtained also on McLeod river.<sup>4</sup>

The gold occurring in these rivers probably has an origin similar to that found in the North Saskatchewan. It may be derived in part from the glacial drift, portions of which have been transported from the Precambrian formations to the northeast.<sup>5</sup> Tyrrell, however, in discussing the origin of the gold of the North Saskatchewan, presents evidence to show that "the fine gold in the river was derived directly from the Cretaceous (Edmonton) rocks which form the banks of the stream, and that these rocks in their turn were an old and very low-grade placer deposit which has come originally from the mountains west of the Upper Columbia valley."<sup>6</sup>

Small quantities of gold occur in the bars of Liard river. Mining operations have been conducted between Devils portage and the mouth of Dease river, but no deposits of economic value have been found below Devils portage.<sup>7</sup>

Mining has been carried on at Porcupine bar, and at Bed-rock bar  $4\frac{1}{2}$  miles lower down. Both of these are on that section of the river having a general north, and south trend, about 25 miles above the mouth of Turnagain river. An auriferous bar occurs at the mouth of Rabbit river, and below Brûlê portage

<sup>1</sup> Dept. of the Interior, Ann. Rept., 1892, pt. 7, p. 28.

<sup>2</sup> Geol. Surv., Can., Ann. Rept., vol. V, pp. 62 D-63 D.

<sup>3</sup> Munitions Resources Commission, Can. Final Report, pp. 156-160.

<sup>4</sup> McEvoy, James, Geol. Surv., Can., Ann. Rept., vol. XI, p. 41 D.

<sup>5</sup> Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. XI, p. 15 A.

<sup>6</sup> Can. Min. Inst., Bull. 34, p. 80.

<sup>7</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. IV, p. 29 D.

the river is wide and filled with low islands and bars, some of which are auriferous. McCullough's bar, on which gold in paying quantities was first discovered on the Liard, occurs in this vicinity. Colours of gold were also obtained on the Liard at the mouth of Fort Nelson river.

Camsell, in reporting on the Peel river and its tributaries, states that "Some coarse colours of gold were panned out from a shovelful of dirt scraped from the rim rock at the mouth of Little Wind river," but only very fine colours were obtained from the gravels of the mountain section of Wind river. Gold is reported to have been found in the gravels of Hungry creek, but "very little indication, however, of placer gold was found on the bars within five miles of its mouth. As the stream rises in a large lake twelve or fifteen miles up, and flows through a low muskeg country to join the Wind river, it appears to be rather an unpromising place for the occurrence of gold, but some of its tributaries which flow through a more hilly country might carry the precious metal."

"In panning for gold on a bar on the Peel river above the mouth of the Wind half a dozen fine colours were obtained, showing that this stream contains more of that metal than the Wind river. Gold is reported to have been found by the Indians in the gravels of the Bonnet Plume river, and some specimens were exhibited; time, however, did not permit us to substantiate this report."<sup>1</sup>

Only a small part of the area underlain by Precambrian formations has been explored. This part is underlain chiefly by granites and gneisses, and these, wherever they have been examined in this and other parts of the Canadian Shield, have as a rule offered very little encouragement to the prospector.

The areas of altered sediments and basic igneous rocks that are found north of lake Athabaska and north of Great Slave lake offer more favourable ground for prospecting. A sample, weighing 5 ounces and consisting of weathered crystalline dolomite, carrying some iron pyrites and a very little brown zinc blende, was examined by the Geological Survey for Mr. E. A. Blakeney and found to carry 2.158 ounces of gold and 0.408 ounce of silver to the ton. The sample was said to have been taken at a depth of 14 feet from one of a series of claims lying within a radius of 10 miles of the mouth of Yellowknife river, on the north side of Great Slave lake.<sup>2</sup>

The glaciation to which the Precambrian area was subjected renders the occurrence of important placers highly improbable.

#### GYPSUM

Gypsum is exposed at many points in the Mackenzie basin. The deposits that are most likely to prove of commercial interest are those occurring on Peace river and in the escarpment to the west of Slave river.

<sup>3</sup>Gypsum is exposed in cliffs (Plate XIII) on both banks of Peace river, almost continuously for a distance of 15 miles below Little rapids. The bottom of the bed is concealed, but the exposed part varies in thickness from a few feet to 50 feet, an exposure of 50 feet occurring on the south side of the river at the foot of the rapids. The surface features indicate that the bed extends back from the river a considerable distance. The gypsum is usually white and

<sup>1</sup>Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XVI, p. 46 CC.

<sup>2</sup>Geol. Surv., Can., vol. XI, p. 33 R.

<sup>3</sup>Macoun, John, Geol. Surv., Can., Rept. of Prog., 1875-76, p. 89.

Camsell, C., Geol. Surv., Can., Sum. Rept., 1916.

massive, but in places is earthy and thin-bedded and holds narrow bands of dolomitic limestone. Thin veins and beds of satin spar are common and anhydrite is occasionally present in rounded nodules and thin beds. The gypsum is overlain by a fractured and broken bed of limestone, but in many places it reaches to the top of the cliff and is covered by only 5 to 15 feet of drift. The deposit is very favourably situated for quarrying.

<sup>1</sup>Gypsum outcrops at several points in the escarpment west and south of the brine springs at the forks of Salt river. Four miles south of the springs, thin-bedded, white or greyish gypsum, containing occasional narrow layers of anhydrite or beds of dolomite, is exposed in the cliffs for a length of half a mile and with a thickness of 40 to 50 feet. North of this it appears to decrease in thickness and is overlain by beds of grey, crystalline dolomite. At Little Buffalo river 10 feet of impure gypsum is exposed at the base of the escarpment. At a point in the escarpment 8 miles southwest of Fitzgerald there is an exposure of 20 feet of thin-bedded, white gypsum overlain by 10 feet of dolomitic limestone. The prevalence of sink-holes on the top of this escarpment, lying to the west of Slave river, indicates that this mineral occurs throughout the greater part of its length.

Ten feet of somewhat earthy, thin-bedded gypsum, of white, grey, or bluish colour, overlain by 20 feet of limestone, outcrops on the west side of Slave river a few miles below La Butte. Immediately below point Ennuyeux, on the same river, thin-bedded, impure gypsum 4 feet thick is exposed near the water level at a medium stage of the water, and at Bell rock, 7 miles below Fort Smith, gypsum is said to have been struck in an excavation.

The numerous exposures in the Slave River country and the topographical features indicate that the mineral is very widely distributed.

At Gypsum point on the north shore of Great Slave lake and along the southwest shore of the north arm of the same lake, thin seams of flesh-coloured gypsum occur between the bedding planes of calcareous sandstone and arenaceous limestone.<sup>2</sup>

A bed of gypsum 130 feet thick is said to have been struck at a depth of 590 feet in well No. 1 of Athabaska Oils, Limited, located on Athabaska river 9 miles below MacKay.

In a section exposed by a small stream in the heart of Bear rock at the mouth of Great Bear river the lowest beds seen consist of reddish and greenish shales, alternating with layers of pink-coloured gypsum and cut by numerous veins and seams of a white, fibrous variety of the same mineral. Thin layers of gypsum interstratified with dark grey, shaly dolomite occur in several places on mount Charles, on Great Bear river,<sup>3</sup> and a bed of gypsum more than 100 feet thick has been observed.<sup>4</sup>

#### IRON

No important deposits of iron ore have yet been discovered in the Mackenzie basin.

Hematite is found interbedded with quartzite of the Tazin series on Beaverlodge bay on the north shore of lake Athabaska. The quartzite here forms a

<sup>1</sup> Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XV, pp. 159 A, 167 A. Geol. Surv., Can., Sum. Rept., 1916.

<sup>2</sup> Cameron, A. E., Geol. Surv., Can., Sum. Rept., 1916.

<sup>3</sup> Bell, J. M., Geol. Surv., Can., Ann. Rept., vol. XII, p. 25 C.

<sup>4</sup> Personal communication from E. M. Kindle.

syncline with limbs dipping at angles as high as 70 degrees; the syncline pitches to the southwest at an angle of 30 degrees. The total area of iron-bearing formation exposed is about 250 acres. The hematite, which also occurs in cavities and along fracture planes, varies from hard blue to soft red, but was not found in economic quantities.<sup>1</sup>

Fragments of iron ore up to 15 pounds in weight are found at a number of points on Steepbank and Moose rivers, tributaries of the Athabaska, and at a point on Steepbank river 4.9 miles from the mouth there is a compacted bed 1 to 2 feet thick made up of fragments of siderite weighing up to 20 pounds. The bed is overlain by a thin capping of bituminous sand and is underlain by a bed of clay 1 to 4 feet thick, which rests upon Devonian limestone. A representative sample of the iron ore was found to contain 35 per cent of iron and 18 per cent of insoluble matter. So far as observed the deposit has no economic value.<sup>2</sup>

Kecle<sup>3</sup> reports hematite as occurring on Gravel river about 10 miles below the mouth of Natla river. "This iron is coarsely laminated with red siliceous slate, having a thickness of from 50 to 100 feet, and is interbedded between the conglomerate and dolomite. An assay of an average sample of this ore was made at the assay office of the Mines Branch, and gave only 25 per cent of iron."

Thin bands of limonite, the thickest of which is only 10 inches, occur in a section of 120 feet of shale exposed on a large stream entering the east side of Mackenzie river 5 miles above the Ramparts. On the southern slope of Bear mountain there is a series of reddish gypsiferous shales 30 feet or more thick. A bed of drab clay shale, which follows the red shale, carries near the top a band of limonite one foot thick.

A bed described as hematite occurs in a sedimentary formation about 20 miles east of the Mackenzie near the eastern end of an Indian trail that leaves the Mackenzie at the mouth of a ravine one mile north of Wrigley. It occurs on the east face of the most easterly range of the Rocky Mountain system. The section of rocks in which the hematite occurs, measured in descending order, is as follows:

	Feet
Red quartzite and sandstone (summit of mountain) (dip 10° to 15° west) . . . . .	500+
Red shale and ferruginous sandstone . . . . .	50
Hematite . . . . .	20
Red sandstone with high percentage of iron . . . . .	50
Dark shales . . . . .	150
Greyish to drab shale . . . . .	225

A sample composed of average samples taken from four different levels in the 20-foot bed was found on analysis to contain 12 per cent of iron.

Very probably the ferruginous band has a considerable areal distribution and is brought near the surface in the northerly and southerly extension of the mountain range. Fossils were not found in immediate association with the bed, but it appears to lie within the limits of the upper Silurian.<sup>4</sup>

A vein carrying fibrous, botryoidal, and micaceous hematite is found at Rocher Rouge, McTavish bay, Great Bear lake; and on some of the more southerly of the group of islands known as Les Iles du Large, Great Slave lake,

<sup>1</sup> Alcock, F. J., Geol. Surv., Can., Sum. Rept., 1916.

<sup>2</sup> Ells, S. C., Mines Branch, Dept. of Mines, Can., Sum. Rept., 1914, p. 63.

<sup>3</sup> "A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and Northwest Territories," p. 50.

<sup>4</sup> Kindle, E. M., Geol. Surv., Can., Sum. Rept., 1919, pp. 1-2 C.

a granular, schistose aggregate of quartz and micaceous hematite occurs in lenticular veins and stringers in a greenish, siliceous sandstone.<sup>1</sup>

Fragments of magnetite and hematite associated with red jasper are found in the Bonnet Plume and Snake rivers. Similar float is widely distributed over a great part of the Peel River basin.<sup>2</sup>

#### LEAD AND ZINC.

Deposits of galena and zinc blende occur at a number of points on the south side of Great Slave lake about 9 miles inland from Pine point. The country rock is a porous, crystalline, dolomitic limestone interbedded with a pebbly limestone lying either in a horizontal attitude or in gently undulating folds. Outcrops, however, are infrequent and the whole region is heavily wooded. Two systems of fracture planes traverse the rock striking north 25 degrees east and south 80 degrees east. The deposits are replacements along bedding or fracture planes and consist of coarse galena, light-coloured zinc blende, and some iron pyrites. Considerable money was spent in 1920 testing these deposits and the results have been reported as encouraging.

Argentiferous galena containing 38.86 ounces of silver to the ton of pure galena is stated to occur at another point in the vicinity of Great Slave lake east of Resolution, but the exact locality is not given.<sup>3</sup> The rock is described as "an association of grey mica schist with a white subtranslucent quartz, more or less thickly coated with hydrated peroxide of iron, carrying some coarsely crystalline galena."<sup>4</sup>

#### NICKEL

No nickel deposits that are of economic value under present conditions have been discovered. Nickeliferous sulphides, however, occur at the east end of lake Athabaska; and there has been considerable prospecting and a number of claims have been staked. The geology of this region was examined by J. B. Tyrrell<sup>5</sup> in 1892 and by F. J. Aleock<sup>6</sup> in 1914. An examination of the mineral claims was also made by Charles Camsell in the summer of 1915.

"The rocks<sup>7</sup> of that portion of the north shore in which the mineral claims were located, namely from the Paris group near the mouth of Grease river to Camille bay, belong to one or the other of the following groups:

"(1) A complex of highly foliated and often contorted crystalline rocks of a gneissoid character, the oldest formation in that district.

"(2) The Athabaska sandstone, flat lying and undisturbed on the south shore of the lake, but somewhat disturbed and metamorphosed to quartzite on the north shore where it comes in contact with the norite.

"(3) A foliated norite younger than, and intrusive into, the Athabaska sandstone as well as into the gneiss.

"(4) Dykes and sills of diabase which are probably genetically connected with the norite.

<sup>1</sup> Geol. Surv., Can., Ann. Rept., vol. XII, p. 36 R.

<sup>2</sup> Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XVI, p. 46 CC.

<sup>3</sup> Bell, R., Geol. Surv., Can., Ann. Rept., vol. XII, p. 103 A.

<sup>4</sup> Geol. Surv., Can., Ann. Rept., vol. XI, p. 33 R.

<sup>5</sup> Geol. Surv., Can., Ann. Rept., vol. VIII, pt. D.

<sup>6</sup> Geol. Surv., Can., Sum. Rept., 1914, pp. 60-61.

<sup>7</sup> Geol. Surv., Can., Sum. Rept., 1915, pp. 123-126.

"The gneiss occupies the lake shore from Robillard river westward. It is the oldest of the four above-mentioned formations and is of no importance from an economic point of view. It is the typical Laurentian granite gneiss with some dark lenses of basic rock and dykes of lighter coloured pegmatite. It is much disturbed and contorted, but has a general trend to the northeast.

"The Athabaska sandstone forms the south shore of the lake, but east of Pine Channel narrows it occupies also part of the north shore where it is somewhat disturbed. Its age is assumed to be Keweenawan. On the south shore it is a white siliceous sandstone lying in a horizontal attitude, but on the north shore of the lake, owing to the intrusion of the norite, it becomes a garnetiferous quartzite and has been tilted at a higher angle with dip to the southward. On the contact of the norite it becomes mineralized with iron sulphides and many mineral claims have been staked on it.

"The norite occupies the area lying between the gneiss and the sandstone on the north side of the lake. It extends from the mouth of Robillard river eastward to the end of the lake, but east of Pine Channel narrows it lies a short distance back from the lake shore and is separated therefrom by a strip of metamorphosed Athabaska sandstone. It is distinctly foliated and cut by many small and irregular veins of quartz. The strike of the foliation varies from northeast to east and the dip is southward at an angle of about 40 degrees. It has apparently been intruded in the form of a great sill or series of sills between the gneiss and the Athabaska sandstone, the former below and the latter above. The actual nature of the intrusion of the norite, whether a single sill or a series of sills, has an important bearing on the occurrence of any ore deposits in it, but this was not definitely determined, though the weight of evidence appears to favour its having reached its present form by a succession of intrusions. It is cut by sheets of diabase and is mineralized at intervals along the same horizons by sulphides of iron. These bunches of mineralized norite constitute the principal "showings" of the district and on them the greater number of mineral claims have been staked.

"Diabase dykes and sills intrude both the gneiss and the norite, but they are generally of small size. They contain some calcite in vugs and small fracture planes, but no regular veins were noticed.

#### MINERAL DEPOSITS

"Practically all the mineral claims that have been located are situated in the norite, and with the exception of the contact phase of the sandstone and some of the dark bands in the gneiss this is the only formation that shows any evidence of important mineralization.

"The norite is a siliceous foliated rock, striking northeasterly and dipping to the southward. At wide intervals on the same strike and at the same horizon in the formation are bodies or bunches of ore weathering red and consisting of pyrrhotite, pyrite, chalcopyrite, and arsenopyrite disseminated through a gangue of silicified country rock. The sulphides are not massive except in small cross fractures, 1 to 2 inches wide, which traverse these bodies. The width of these bodies ranges from 5 to 20 feet and the boundaries in this direction are fairly definite. The length is also variable and while most of them are only a few feet in length the maximum of those seen is perhaps 100 feet. Along the strike the sulphides gradually diminish in quantity until they disappear altogether. The



bodies are isolated from each other and are not continuous; but by following out the strike of the foliation of the norite another body may be found several hundred feet away. In places quartz stringers 2 to 6 inches wide crosscut the formation and in these the principal sulphide is arsenopyrite with sometimes specular hematite, pyrite, or galena.

“Deposits of this character are found in several places in the belt of norite lying between Sucker bay and Norite bay and extending along the strike of the norite from the islands about Channel point northeastward for several miles inland. Typical deposits of this character are those on the Norah, Victory, Excelsior, Garrett, and North Star mineral claims. The metals found by assay to occur in them are nickel and copper, but the average value is not high. Some platinum is also said to have been found.

“Samples 1, 2, 3 were collected by the writer from the more important localities where some development work had been done and assayed both by the Mines Branch in Ottawa and by J. A. Kelso, director of industrial laboratories in the University of Alberta. Samples 4, 5, 6 were collected by F. J. Alcock during 1914. The results of analyses are as follows:

*Analyses of Fond du Lac Ores*

—	1	2	3	4	5	6
Copper.....	0.09	Nil	.....	Trace	Trace	6.65
Nickel.....	Nil	Nil	0.10	Trace	0.20	1.07
Gold.....	.....	Nil	Nil	Nil	Nil	Nil
Silver.....	.....	Nil	Nil	Nil	Nil	Nil

1. From the Norah mineral claim, carrying disseminated pyrrhotite and chalcopyrite. (Analysed by Mines Branch, Dept. of Mines.)
2. From the Norah mineral claim. (Analysed by J. A. Kelso, University of Alberta.)
3. From the Garrett mineral claim, formerly known as the Lake Point. (Analysed by J. A. Kelso, University of Alberta.)
4. From the Norah mineral claim. (Analysed by Mines Branch, Dept. of Mines.)
5. From the Garrett mineral claim, formerly known as the Lake Point. (Analysed by Mines Branch, Dept. of Mines.)
6. Picked sample containing small quantities of pyrite, chalcopyrite, and pyrrhotite from one of the small fractures on the Paris claim.

“On the Paris group of claims, or what was originally known as the Athabaska group, the rock is a dark, fine-grained variety associated with a porphyritic granite gneiss. The rock outcrops in a low cliff on the shore of the lake and is sparingly mineralized with pyrite and pyrrhotite which is disseminated through it and gives a rusty stain to the outcrop. In narrow fracture planes there is a little more iron sulphide, apparently secondarily deposited, but nowhere does there seem to be any concentration of the sulphides sufficient to form an ore-body of workable dimensions. Assays show the principal valuable metal at this point to be nickel.

“At this point native silver was said to have been found in the small fractures traversing the rock, but I could find no evidence of that metal.

“The claims situated at the head of Camille or Fishing bay are of somewhat different character. Here the prevailing rock is a garnetiferous gneiss presumably altered Athabaska sandstone, intruded by sheets of norite. The

outcrop of the quartzite is red with iron oxide and constitutes what is known as the lead on which the claims have been staked. The deposits are of a contact metamorphic nature with mineralization by pyrite and pyrrhotite as a result of the intrusion of the norite. The sulphides are disseminated through the gneiss over a considerable area along a well-defined strike, but do not appear to be sufficiently concentrated anywhere to form important ore bodies.

"In conclusion it is the writer's opinion that, while the mineral deposits that have been taken up in the norite may be of value at some time in the future, unless more important discoveries are made the remoteness of the district from railway transportation and from any large centres of population, and the present undeveloped state of the surrounding country render their exploitation impracticable at the present time."

#### PETROLEUM AND NATURAL GAS

Attention has been directed for some time to the possibilities of discovering petroleum and natural gas in the Mackenzie basin where numerous striking indications of their occurrence have long been known. Unfortunately our knowledge of the geological structure is too limited to permit of our offering suggestions in detail as to where explorations might be carried on with the greatest likelihood of success. Boring operations have been conducted along Athabaska and Peace rivers where strong flows of gas were struck in two or three wells, and petroleum-bearing strata on Peace river have been penetrated.

Oil and gas indications are found in the sediments of Cretaceous and Devonian age, both of which are of wide distribution.

*Devonian.* The discovery of oil near Norman in 1920 is of great importance; it has attracted the attention of the public to the possibilities of Mackenzie River basin as no other event has done. It has been known for a century that oil seepages issue from the Devonian rocks of this area. It remained for the boring near Norman to demonstrate the occurrence of an oil pool in these rocks. There is a vast area that may prove favourable prospecting ground. Rocks of the Devonian system are of wide distribution and stretch from near the mouth of Mackenzie river south to beyond lake Athabaska. They are overlain in places by rocks of Cretaceous and Tertiary age and pass beneath Cretaceous sediments on Peace and Athabaska rivers.

During the summer of 1920 boring was carried on by the Imperial Oil Company at Windy point on the north shore of Great Slave lake and at a point on Mackenzie river 45 miles below Norman.

It is reported that a depth of about 300 feet was reached at Windy point and about 783 feet in the well below Norman. In the latter a strong flow of oil was struck at a depth of about 783 feet. A lighter flow was struck at a depth of 270 feet. This is of good quality as is shown by the following statement of the results of an analysis made in the laboratory of the Mines Branch, Department of Mines, Ottawa. The quality of the oil struck at greater depth is reported to be even better. The oil from a depth of 270 feet is opaque, dark olive green, with an odour between those of kerosene and gasolene. It is completely soluble in petroleum ether, indicating that there is no asphalt base present.

Specific gravity at 15.5° C. 0.839.

Distillation	Continuous method	Engler intermittent method	Specific gravity	Colour
First drop.....	60° C.	59° C.		
Up to 100° C.....	6.5 c.c.	7 c.c.	0.687	Colourless.
100° to 150° C.....	12.0 c.c.	14 c.c.	0.735	Colourless.
150° to 200° C.....	12.5 c.c.	12 c.c.	0.783	Colourless, slightly opalescent.
200° to 250° C.....	10.5 c.c.	11 c.c.	0.816	Colourless, opalescent.
250° to 300° C.....	10.5 c.c.	10 c.c.	0.837	Very faint yellow opalescent.
300° to 350° C.....	10.0 c.c.	12 c.c.*	0.861	Straw yellow opalescent.
Residue (by difference).....	38.0 c.c.	34 c.c.	0.929	Dark brown, with olive green tinge.

\*Probably some "cracking" here.

Specific gravity of original oil calculated from above figures—0.837.

There was insufficient residual oil from distillation to determine its viscosity, but at 100° F it flowed very slowly, and at 210° F. comparatively rapidly, from a Redwood viscosimeter.

Calorific value.

Calories per gram, gross, 10320

Sulphur—0.2%.

B. T. U. per lb., gross, 18582

In many places the Devonian strata are highly bituminous in character, and several petroleum springs are known.

The upper beds penetrated by the boring at Vermilion chutes are impregnated with bitumen, and strata exposed near La Butte on Slave river and in several places around the western arm of Great Slave lake are also highly bituminous. Bitumen occurs in limestone at the Ramparts, in some of the dark argillaceous shales exposed at the water's edge along Grand View, and in shales in a small plateau lying a short distance east of the Mackenzie 15 miles below Grand View. The shales in this plateau are reddened in places by combustion of the bituminous matter. Fifteen miles farther down the river evenly-bedded, highly bituminous, black, Devonian shales occur. "The laminæ, when freshly separated, are moistened on the surface with an oily liquid, and burn when thrown into the fire, and patches of red shales, marking the sites of former fires, alternate with the dark varieties. The shales are exposed in the right bank for some miles, or almost as far as old Fort Good Hope. They dip down the river at a low angle."<sup>1</sup>

Petroleum springs issue from the Devonian rocks at a number of points. Probably the best known are those that occur at Windy point on the north shore of Great Slave lake.

"The springs are situated a couple of hundred yards from the shore, at the base of a low limestone cliff, which runs inland from the lake, and are three in number, each of them being surrounded with a small basin, three to four feet in diameter, filled with inspissated bitumen, while the soil and moss for some distance away are impregnated with the same material. A small quantity of pitch is annually taken from these springs and used for boat-building purposes, while a much larger supply could be obtained if needed. A sulphur spring resembling those at Sulphur point on the south shore of the lake, but much more copious, issues from the foot of the cliff in close proximity to the bituminous springs, and feeds a considerable stream.

<sup>1</sup>McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. IV, p. 110 D.

"The rock through which the petrolcum ascends here is a heavily bedded, greyish, rather coarsely crystalline, cavernous dolomite, and is entirely unlike the bituminous beds south of the lake and down the Maekenzie, which in most cases consist of calcareous shales. The dolomite is everywhere permeated with bituminous matter, which collects in the numerous cavities, and oozing up through the cracks, often forms small pools on the surface of the rock.

"Sulphur and tar springs are reported to occur at a point about half-way between this and Fort Rae, but as I did not hear of them until I had left the lake, I was unable to visit them. A tar spring is also known to exist under the surface of the water in the deep bay immediately east of the Big Island fishery, as many of the boulders and rocks along the shore in this neighbourhood are coated with bitumen which has been washed ashore, and hummocks of ice stained with the same material are often observed. On the south shore bituminous shales and limestones occur at several points."

A range of hills composed of dolomite rises from the shore on the north side of Sulphur bay which lies to the north of Windy point. Tar springs comparable in size to those of Windy point are found on these hills at an elevation of 200 feet above the lake and a mile inland.<sup>1</sup>

Some of the limestone in the Rock-by-the-river-side is slightly bituminous and Franklin observed "sulphurous springs and streams of mineral pitch issuing from the lower parts of the limestone strata" exposed in Bear rock.

McConnell states that "near Fort Good Hope several tar springs exist, and it is from these that the Hudson's Bay Company now obtain their principal supply of pitch. The springs are situated at some distance from the river and were not examined."<sup>2</sup>

The Devonian strata exposed on Athabaska, Peace, and Maekenzie rivers are nearly horizontal. On Athabaska river and its tributaries there is some local doming, and limestone is brought to the surface by an anticline between 35 and 40 miles up Mikkwa river, a tributary of the Peace.

A. E. Cameron, in his report for 1917, describes the structure of the Devonian system on Great Slave lake as follows:

"Stratigraphic studies have revealed the presence of a gentle anticline stretching across the lake from Pine point on the south shore to Nintsi (Windy) point on the north shore. On the south shore the apex of the anticline is shown on the east side of Pine point and the lowest beds exposed show the Pine Point series of bituminous limestones and limy shales. The presence of higher strata, the overlying Presqu'ile dolomites, both to the east on Burnt islands and to the west at Presqu'ile point, clearly demonstrates the antilinal structure. On the north shore the crest appears to lie in the erosion basin of Sulphur bay. The Presqu'ile dolomites are exposed on the east shore of Nintsi point, at various points on the shores of the bay, and eastward to Jones point; whereas the overlying Slave Point limestones are shown on Slave point west of Nintsi point and again near House and Moraine points northeast of Jones point.

"Structural conditions suggestive of gentle antilinal folding are noticeable in the limestone outcrops on Buffalo river and those exposed on Hay river above the falls. Exposures are confined to the valley floors when the rivers have cut down into the Devonian sediments and on account of the overburden of glacial drift the extent of the folding was not observable.

<sup>1</sup> Cameron, A. E., Geol. Surv., Can., Sum. Rept., 1916.

<sup>2</sup> Geol. Surv., Can., Ann. Rept., vol. IV, 1891, p. 31 D.

"As shown by the oil seepages and tar pools on Nintsi point the Presqu'île dolomites appear as the most probable oil horizon of the district and as these sediments are exposed on the limits of the anticline, the possibilities of an oil-producing field existing on the shores of the lake are not very great.

"A thick series of soft clay shales is exposed on Hay river, which from the stratigraphical relation would appear to overlies the dolomites. If the dolomite horizon can be found elsewhere in the district under suitable structural conditions and overlain by these impervious shales it may be worth investigating with a drill.

"On Hay river, above the falls, limestone outcrops in the valley show gentle undulations forming anticlines and synclines of a low order. The limestones here exposed represent upper members of the Hay River limestones which overlies the thick series of shales above mentioned.

"It is to be noted that the section exposed on Peace river shows members of the Simpson shale series unconformably overlying the gypsum series of upper Silurian age, and thus the middle Devonian section as exposed on Great Slave lake is here absent. It is, therefore, possible that the dolomites would not be found underlying the shale series in the folded area above the falls on Hay river, or, if present, they would probably be somewhat thinner in their development than is shown on the shores of the lake. If drilling operations were conducted on Hay river, a thickness of about 1,000 feet of sediments would have to be pierced before the Presqu'île dolomites would be reached."

Details of structure in the Devonian formation below the point where the Mackenzie reaches the mountain system have not been worked out. Anticlinal folds are common and enter into the structure of such features as the Rock-by-the-river-side and the several ridges that trend east and west in the vicinity of the mouth of Carcajou river. The structural features of Franklin and Bear mountains conform in a general way to the trend of Mackenzie mountains and it is not improbable that local undulations occur in the intervening broad valley through which the Mackenzie flows.

A few borings have been made into or through the Devonian limestones and shales on Athabaska river, but no petroleum has been struck. Below McMurray a number of wells have been sunk on local domes; at McMurray and 9 miles below MacKay, wells have penetrated to the Precambrian rocks, and a short distance above Pelican river on the Athabaska a boring was carried through the Cretaceous and 1,000 feet into the Devonian. In the last well a flow of gas was encountered at a depth of 2,040 feet. At Vermilion chutes a well was sunk to a depth of 860 feet through Devonian strata. The few borings that have been made have not given encouraging results, but the field for exploration is exceedingly broad.

*Cretaceous.* The most striking surface indication in the section of country underlain by Cretaceous rocks is the enormous deposit of bituminous sand occurring at the base of the Cretaceous sediments on Athabaska river and its tributaries. This bituminous sand is described elsewhere in this report.

A spring of natural gas is situated at Tar island on Peace river about 25 miles below Peace River Crossing. The gas rises with salt water and some tar from among the gravel and boulders at the upper end of the island. The flow of gas has been roughly calculated to be about 3 or 4 cubic feet per minute.<sup>1</sup> On Peace river and around Lesser Slave lake bitumen has been found at a

<sup>1</sup> Camsell, C., Geol. Surv., Can., Sum. Rept., 1916.

number of places lining cracks in nodules, and a tar spring is reported as occurring near the mouth of Marten river on Lesser Slave lake.<sup>1</sup>

Franklin mentions having observed a bituminous liquid trickling down the steep cliff on the northwest part of Garry island at the mouth of the Mackenzie.<sup>2</sup> On the right bank of Peel river, 10 miles below the lower canyon, a 3-foot vertical fissure cutting across sandstone and shales is filled with a light, soft, carbonaceous substance which burns readily with a red flame, leaving very little ash. This substance has its origin probably in the bitumen of the adjacent rocks.<sup>3</sup>

Gas springs are numerous. The most important occurs at the mouth of Little Buffalo river, a tributary of the Athabaska. The gas "issues from the surface in numerous small jets distributed over an area fifty feet or more in diameter. Some of the jets burn steadily when lighted, until extinguished by heavy rains or strong wind, and afford sufficient heat to cook a camp meal. A second spring was noticed on the left bank of the Athabaska about thirteen miles below the mouth of Pelican river. The volume of gas escaping here is less than at the mouth of Little Buffalo river. . . . . Escaping jets of gas were also noted at several points farther up the river, but these were mostly small and may possibly be due to decaying vegetable matter."<sup>4</sup>

Sulphur springs are of common occurrence. Among the number observed are those occurring on the left bank of Christina river 12 miles from its mouth,<sup>5</sup> on the north side of Clearwater river 4 miles below Cascade rapid and other points,<sup>6</sup> on Firebag river,<sup>7</sup> on Jackfish and Little Buffalo rivers west of Slave river,<sup>8</sup> at Sulphur point on the southwest shore of Great Slave lake, north of Brûlé point on the north shore of the same lake,<sup>9</sup> and at La Saline on Athabaska river.

It was thought that the bitumen of the McMurray sandstone on the Athabaska had probably been derived from petroleum by the evaporation of the lighter hydrocarbons and by chemical changes and that at some distance from the outcrop this sandstone might carry petroleum. With a view to testing this hypothesis the Dominion Government undertook boring operations at two points on the river where it was known that the sandstone had a considerable depth of covering. Wells were sunk at Athabaska and near Pelican river.

At Athabaska boring was carried on during portions of the summers of 1894, 1895, and 1896, and a depth of 1,770 feet was attained. Great difficulty was encountered on account of the caving of shale. It was believed that drilling ceased in the Clearwater shales. Gas in small quantities was struck at several horizons.

<sup>1</sup> Ogilvie, Wm., Dept. of the Interior, Ann. Rept., 1889, pt. 8, p. 94.

<sup>2</sup> "Narrative of a second expedition to the shores of the polar sea in the years 1825, 1826, and 1827," p. 37.

<sup>3</sup> Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XVI, p. 47 CC.

<sup>4</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 64 D.

<sup>5</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 39 D.

<sup>6</sup> Bell, Robert, Geol. Surv., Can., Rept. of Prog., 1882-83-84, p. 26 CC.

<sup>7</sup> Dowling, D. B., Geol. Surv., Can., Ann. Rept., vol. VIII, p. 67 D.

<sup>8</sup> Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XV, pp. 161 A, 166 A.

<sup>9</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. IV, pp. 69 D., 75 D.

*Log at Well at Athabaska<sup>1</sup>*

	Feet
Drift. . . . .	0-14
Grey shale, soft and caving badly. . . . .	14-245
(At 23 feet, 136 feet, and 245 feet, hard streaks were met. Below the hard streak at 245 feet a strong flow of gas.)	
Soft shale. . . . .	245-400
(A heavy flow of gas at 334 feet, a hard streak at 338 feet).	
Shale, slightly harder. . . . .	400-425
(At 425 feet, a hard stratum about 1 foot thick).	
Grey shale. . . . .	425-500
Darker shale, soft, caving badly. . . . .	500-550
Shale with streaks of sand rock 1 to 2 feet thick. . . . .	550-580
Dark shale, very soft. . . . .	580-825
(At 780 feet salt water was struck, and a strong flow of gas).	
Shale, harder and bluer. . . . .	825-900
Soft, dark shale. . . . .	900-1,015
Hard, light shale. . . . .	1,015-1,037
Dark shale. . . . .	1,037-1,090
Sandstone, carrying water. . . . .	1,090-1,130
Dark shale, caving badly. . . . .	1,130-1,170
Dark shale with layers of sandstone. . . . .	1,170-1,207
Dull reddish shale and sandstone. . . . .	1,207-1,233
Dark, soft shale. . . . .	1,233-1,237
Light grey shale, very hard. . . . .	1,237-1,242
Light grey shale, soft. . . . .	1,242-1,247
Dark shale, soft. . . . .	1,247-1,255
Sandstone, very hard. . . . .	1,255-1,260
Soft, dark shale. . . . .	1,260-1,285
Hard sandstone. . . . .	1,285-1,310
Dull reddish shale and sandstone, soft. . . . .	1,310-1,323
Reddish shale. . . . .	1,323-1,338
Sandstone and dark shale. . . . .	1,338-1,350
Dull reddish shale and a little sandstone. . . . .	1,350-1,391
Sandstone with layers of dark shale. . . . .	1,391-1,435
Hard sandstone with soft streaks. . . . .	1,435-1,448
Sandstone and dark shale. . . . .	1,448-1,461
Dark shale (thin streaks of lignite). . . . .	1,461-1,491
Light, hard shale. . . . .	1,491-1,531
Shale, not so hard. . . . .	1,531-1,540
	1,540-1,566
Hard sandstone. . . . .	1,566-1,576
Hard shale. . . . .	1,576-1,601
Hard shale with soft streaks. . . . .	1,601-1,613
Hard shale. . . . .	1,613-1,626
Very hard. Ironstone boulder. . . . .	1,626-1,633
Hard shale (a little gas about 1,650 feet). . . . .	1,633-1,682
Hard and soft shale alternating. . . . .	1,682-1,689
Shale and sandstone alternating. . . . .	1,689-1,722
Shale with a little sandstone. . . . .	1,722-1,731
Shale, soft and dark. . . . .	1,731-1,736
Hard sand-rock. . . . .	1,736-1,747
Shale. . . . .	1,747-1,752
Shale and sandstone. . . . .	1,752-1,759
Shale. . . . .	1,759-1,763
Hard, supposed sandstone . . . . .	1,763-1,767
Soft shale. . . . .	1,767-1,770

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<sup>1</sup> Geol. Surv., Can., Ann. Repts., 1894-5-6.

<sup>1</sup> Dawson gives the following section at Athabaska, obtained from a natural exposure and from the bore-hole, the zero datum being the top of the bore-hole or about 1,660 feet above sea-level.

<i>Height</i>	<i>Thickness of Formation</i>
Feet	Feet
Top of bank.	
180—Yellowish sandstones, thin beds, with some ironstone: <i>Foxhill</i> or <i>Laramie</i> . . . . .	15
165—Probably all grey shales, with some thin sandstone layers; not well exposed.	
<i>Depth</i>	
0—Top of bore-hole.	
1,090—Grey and blackish shales, often very soft, with occasional thin, hard layers of sandstone or ironstone. Much gas at different levels between 245 and 780 feet: <i>La Biche shales</i> . . . . .	1,255
1,130—Grey sandstone, with a flow of soft water: <i>Pelican sandstone</i> . . . . .	40
1,233—Dark shales, often soft, a little sandstone: <i>Pelican shales</i> . . . . .	103
1,461—Grey sandstones and grey, reddish, and blackish shales; the sandstone sometimes very hard and probably nodular, as in outcrop at Grand Rapids: <i>Grand Rapids sandstone</i> . . . . .	228
1,770—Dark and light-grey shales, generally hard, with some sandstone layers, particularly towards the base: <i>Clearwater shales</i> . . . . .	309 (or more)
Total . . . . .	1,950

Near Pelican river the boring was carried to a depth of 821 feet 6 inches in 1897 and continued to a depth of 837 feet in 1898. The bituminous sands were met at a depth of 750 feet and were penetrated 87 feet. They were found to consist of soft sandstone saturated with bitumen. Strong flows of gas were struck at 750 and 773 feet, and at 820 feet a tremendous flow was struck, the roaring of which could be heard at a distance of 3 miles or more. The flow was so strong that no progress could be made in drilling, and work was abandoned until 1898, when it was thought the force of the gas would be decreased sufficiently to permit of further operations.

<sup>2</sup>But though there was a seeming decrease of pressure, upon operations being resumed in 1898, "the seeming decrease was found to be in a great measure due to the closing up of the outlet at the bottom of the casing by an asphalt-like mixture, composed of maltha or petroleum tar and sand. In fact, when boring operations were resumed on June 17, the difficulty was found to be intensified by the accumulations of this asphalt-like maltha in the bottom of the bore.

"The rapid expansion of the gas produced a very low temperature, and this chilled and solidified the tar, or maltha, until it became as adhesive as wax. As the tools cut it loose the gas would carry it up through the bore, until from bottom to top it was almost one mass of sand and tar. The only way it could be extracted from the sand-pump was by heating the latter over a fire; even then very little could be got out at one time, it being so thick that it was almost impossible to force it up into the pump. I used different sorts of tools to cut it off the walls and clean it out, but the longer we worked

<sup>1</sup> Geol. Surv., Can., vol. XII, p. 14 A.

<sup>2</sup> Geol. Surv., Can., vol. XI, p. 32 A.



at the bore the greater the quantity of tar accumulating on the sides of the casing and tools." By using smaller casing the hole was carried to a depth of 837 feet, when another flow of gas was met, nearly equal in volume to that met at 820 feet, and the work was stopped.

<sup>1</sup>A sample of the gas taken by F. H. McLearn was analysed by E. Stansfield, of the Mines Branch, Department of Mines, with results as follows:

CO <sub>2</sub>	1.0 per cent
O	2.9
Methane	83.5
N	12.6

Assuming oxygen present is due to contamination with air the composition would be

CO <sub>2</sub>	1.2 per cent.
Methane	97.0
N	1.8

*Log of Well Near Pelican<sup>2</sup>*

	Feet
Sand and gravel. . . . .	1-86
Very soft, dark-bluish shale. . . . .	86-101
Soft sandstone. . . . .	101-105
Very soft, dark-bluish shale. At 185 feet slightly saline water	105-185
Rather hard, reddish brown shale. . . . .	185-225
Sandstone. At 225 feet water. . . . .	225-234
Sandstone and brown shale. . . . .	234-245
Hard, grey shale. At 253 feet more water and gas. . . . .	245-253
A light, greenish-grey shale. . . . .	253-280
Soft greenish-grey shale, cement-like. . . . .	280-290
Brown shale, with strata of grey shale. . . . .	290-308
Brown shale. . . . .	308-310
Hard sandstone. More gas and water. . . . .	310-311
Brown shale and sandstone in alternate strata. . . . .	311-328
Sandstone. . . . .	328-340
Brown shale. . . . .	340-353
Hard sand-rock, with layers of softer rock. . . . .	353-365
(At 355 feet struck maltha and gas).	
Sandstone rather hard . . . . .	365-410
Brown shale. . . . .	410-427
Hard, brown shale. . . . .	427-450
Sandstone. More gas and water. . . . .	450-465
Grey shale. . . . .	465-526
Ironstone. . . . .	526-532
Grey shale. . . . .	532-553
Sandstone. . . . .	553-556
Very hard, probably ironstone. . . . .	556-558
Very hard sandstone . . . . .	558-563
Brown shale. . . . .	563-573
Grey shale, streaks of sandstone. . . . .	573-590
Grey shale, brown shale, and sandstone in alternating strata; the cuttings show traces of maltha. . . . .	590-620
Grey shale. Strong flow of gas at 625 feet; considerable maltha coming away with the water . . . . .	620-625
Very hard sandstone. . . . .	625-643
Soft, grey shale. . . . .	643-648
Hard sandstone. . . . .	648-652
Soft, grey, sandy shale. . . . .	652-665
Ironstone. . . . .	665-675
Soft, grey shale. . . . .	675-684
Hard sandstone. . . . .	684-685
Soft, dark-grey shale. . . . .	685-703
Hard sandstone. . . . .	703-713
Soft, grey, sandy shale. . . . .	713-718
Hard sandstone. . . . .	718-723
Sandstone. . . . .	723-733

<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1916, p. 151.

<sup>2</sup> Geol. Surv., Can., Sum. Rept., 1897 and 1898.

## Log of Well Near Pelican—Concluded

	Feet
Soft, grey shale. . . . .	733-743
Soft, grey shale, with streaks of soft sandstone. Strong flow of gas at 750. A heavy oil mixed all through the sandstone and shale. . . . .	743-758
Soft, dark-grey shale and soft sandstone. Heavy oil throughout. At 773, a heavier flow of gas. . . . .	758-781
Alternate strata of soft, grey shale and soft sandstone. Increased quantities of heavy petroleum. Gas increasing in volume. . . . .	781-800
Same as foregoing. At 820 feet, a tremendous flow of gas of which the roar could be heard three miles or more	800-820
Soft sandstone. Hard streak, and light flow of gas at 830	820-830
Soft sandstone. . . . .	830-836
Iron-pyrites nodules embedded in cement-like sandstone. Very strong flow of gas . . . . .	836-837

<sup>1</sup>Dr. Dawson gives the following section from this well:

<i>Depth from surface Feet</i>	<i>Thickness of formation Feet</i>
86—Sand and gravel (surface deposits). . . . .	86
185—Dark, bluish-black, soft shales, with some sandstone in upper part. <i>Pelican shales</i> . . . . .	99
465—Greyish sands and sandstones, and brownish and greyish shales. <i>Grand Rapids sandstones</i> . . . . .	280
750—Greyish and brownish shales, alternating with thin beds of hard sandstone and ironstone. <i>Clearwater shales</i> . . . . .	285
837—Sands and clays often saturated with heavy oils and tar. <i>Tar sands</i> . . . . .	87 (or more).

A number of wells have been sunk along the Athabaska in recent years in search of petroleum, but the results have not been satisfactory.

The Pelican Oil and Gas Company, Limited, did some boring a few miles above Pelican river and in Well No. 3 of this company a strong flow of gas was struck.

Log of Well No. 1, Pelican Oil and Gas Company<sup>2</sup>

	Feet
Blue and yellow shale. . . . .	1 - 66
White and grey shale (water). . . . .	66 - 82
Blue shale. . . . .	82 - 200
Blue and brown shale. . . . .	200 - 235
Brown shale. . . . .	235 - 285
Grey-brown shale. . . . .	285 - 331
Sand rock (hard). . . . .	331 - 352
Shale. . . . .	352 - 365
Sand rock. . . . .	365 - 425
Shale. . . . .	425 - 507
Brown shell (hard) . . . . .	507 - 509½
Grey shale. . . . .	509½ - 538
Shell. . . . .	538 - 540
Sandstone. . . . .	540 - 546
Shale . . . . .	546 - 575
Hard shell. . . . .	575 - 581
Grey shale, streaks of sandstone. . . . .	581 - 644
Strong flow gas . . . . .	625
Grey shale (gas). . . . .	644 - 653
Grey shale (soft and cement-like). . . . .	653 - 666
Sand rock. . . . .	666 - 671
Grey shale. . . . .	671 - 688
Hard, brown shell. . . . .	688 - 689

<sup>1</sup>Geol. Surv., Can., vol. X, p. 19 A.

<sup>2</sup>Huntley, L. G., Am. Inst. Min. Eng., Bull. 102, p. 1350.

*Log of Well No. 1, Pelican Oil and Gas Company—Concluded.*

	Feet.
Dark grey shale. . . . .	689 - 740
Hard shell. . . . .	740 - 741
Dark grey shale. . . . .	741 - 766
Hard shell. . . . .	766 - 767
Dark grey shale, sandy . . . . .	767 - 843½
Sandy shale. . . . .	843½ - 872
Sandy shale . . . . .	872 - 882
Coarse rock mixed with heavy oil. . . . .	882 - 887
Shale and sand. . . . .	887 - 898
Hard rock. . . . .	898 - 903
Lime carrying oil. . . . .	903 - 997
Limestone. . . . .	997 - 1,051
Hard, flinty shell (strong flow of gas under shell). . . . .	1,051 - 1,053½
Limestone. . . . .	1,053½ - 1,158
Hard, lime shell. . . . .	1,158 - 1,159
Limestone. . . . .	1,159 - 1,192
Hard shell (gypsum). . . . .	1,192 - 1,197
Blue shale and gypsum. . . . .	1,197 - 1,293
Hard, lime shell. . . . .	1,293 - 1,296
Lime rock. . . . .	1,296 - 1,538
Lime, shale, and lime rock. . . . .	1,538 - 1,560
Grey shale and lime (gas) . . . . .	1,560 - 1,700
Limestone. . . . .	1,700 - 1,784
Hard shell. . . . .	1,784 - 1,790
Lime rock (shale streaks). . . . .	1,790 - 1,875
Hard shell. . . . .	1,875 - 1,879
Layers of limestone and shale. . . . .	1,879 - 2,040
Strong flow of gas. . . . .	2,040
Limestone and shale, interstratified. . . . .	2,040 - 2,069

Several companies have carried on boring operations along the river from McMurray to some distance below MacKay and in some of the wells small quantities of oil have been struck. The logs of two wells bored at the mouth of Horse creek in the vicinity of McMurray are given on page 125.

*Log of Well No. 1, Athabaska Oils, Limited, Located 9 Miles Below MacKay.*

	Feet
Top soil. . . . .	1- 4
Cemented oil sand. . . . .	4- 18
Oil stratum. . . . .	18- 78
Shale. . . . .	78- 98
Oil stratum. . . . .	98- 155
Shale. . . . .	155- 330
Limestone. . . . .	330- 395
Shale. . . . .	395- 415
Limestone. . . . .	415- 590
Gypsum. . . . .	590- 720
Limestone. . . . .	720- 912
Red rock. . . . .	912- 975
Hard, reddish flint sand or rock. . . . .	975-1,105
Reddish quartz or rock. . . . .	1,105-1,130

Salt water was struck at depths of 765 and 1,000 feet. A small quantity of petroleum was struck in the upper part of the well.

During the summer of 1916 boring operations were conducted at the upper end of Vermilion chutes and at a point on Peace river 17 miles below Peace River Crossing.

At Vermilion chutes boring was carried to a depth of 860 feet through Devonian limestone and shale. The upper beds are porous and impregnated with

bitumen. The well below Peace River Crossing was drilled to a depth of over 1,100 feet, and at 857 feet a small quantity of heavy black oil was struck. This was cased off and the hole was continued to a depth of over 1,100 feet when a very strong flow of gas was struck. An analysis of a sample of the oil is given in the Summary Report of the Geological Survey, Canada, for 1916.

F. H. McLearn in his report for 1917 states:

"The discovery of oil this summer in the No. 2 well of the Peace River Oil Company, about 15 miles below Peace River, lends particular interest to this part of the district. The well is situated on the high strata where the south dip flattens out northward. The oil occurs at two horizons, beds of sandstone in both cases, near the base of the Loon river and not far above the limestone contact. The upper sandstone is met with from 842 to 948 feet in the drill-hole. Above 852 feet this bed yielded gas; from 852 to 905 feet it contained a highly viscous oil; from 905 to 910 feet it carried salt water, and from 910 to 948 feet was firmly cemented and barren of oil, gas, or water. Below this is a 14-foot shale bed followed below from 962 to 1,032 feet by the second oil sand. This is impregnated with an oil of somewhat better quality. This horizon would produce a few barrels per day. An analysis by the Mines Branch (Edgar Stansfield, Chief Engineering chemist) gave:

(a) Specific gravity at 60°F.....	981	
(b) Distillation test.		
Below 150° C.....		2.0 % by volume naphtha.
"    150-200.....		4.87
"    200-250.....	5.3	} 66.3 % illuminating oils.
"    250-300.....	56.2	
"    300-325.....	5.2	
Residue and loss.....		26.5 % lubricating oil.

"Oil of similar gravity was found at the corresponding horizons in the No. 1 well 1½ miles downstream. The two sandstones are of less thickness here and the shale between thicker. The thinning of these oil sands northward no doubt limits the possibilities of exploration in that direction, since with their disappearance there would be no reservoir to contain oil. As far as structure alone is effective, it should be noted that it is of a gentle nature north of the wells, with very low dips. The conditions obtaining at the wells, therefore, might be expected to prevail over a considerable area from the wells north, limited in that direction more particularly by the wedging out of the sandstones. Were the strata thrown into undulations of a more pronounced nature, more circumscribed areas favourable to boring could be pointed out. In accordance with the recently stated theory of David White, it is not improbable that the heavy gravity of the oil is related to this gentle structure.

"To the west past Dunvegan and St. John, no favourable structures for boring were located. At Hudson Hope there is a broad low anticline. The anticline at the Gates is broken by a fault. About 600 feet below river level the upper shales, sandstones, etc., of the Bull Head Mountain sandstone would be met with. Below this the lower sandstones of that formation are too massive to serve as a suitable reservoir. The Triassic shales and sandstones must be over 3,000 feet below river level at Hudson Hope.



no proof that it does not occur at other points where the McMurray sandstone is overlain by impervious strata. The Loon River formation of Peace river is considered the equivalent of the McMurray.

Our knowledge of the structure of the Cretaceous formations in the Athabaska River district is very limited, but such information as we have may be of use to those anticipating further operations. The Cretaceous sediments of this district are nearly horizontal, and rest upon the Devonian with an unconformity so slight that it can be detected only by examination of the contact for a distance of several miles. Between Grand rapids and Pelican rapids, the dip of the Cretaceous strata is about  $5\frac{1}{2}$  feet a mile south, and between Pelican rapids and Athabaska the dip is about 10 feet a mile up the river. This greater dip between Pelican rapids and Athabaska may be due, in part, to its southwest direction and may indicate that the true dip of the Cretaceous strata on the Athabaska is west of south. A low anticline crosses the river near Crooked rapids; the dip on each side is only 3 or 4 feet per mile. Below McMurray the strata are probably nearly horizontal and may have a slight north or northwest dip.

To test the McMurray sandstone where it is overlain by impervious strata it will, therefore, be necessary to conduct boring operations to the south or southwest of its outcrop.

The oil struck in the shallow wells of the Athabaska Oils, Limited, opposite the mouth of Dover river, occurs in a hollow of the Cretaceous-Devonian unconformity. This depression is 12 miles long in the direction of the river and opposite the mouth of Dover river has a depth of about 140 feet below the limestone rim. Farther downstream there is a similar smaller depression.<sup>1</sup>

The problem of the origin of the hydrocarbons of the McMurray sandstone has not been solved. One theory is that they were derived from underlying bituminous sediments of Devonian age; another, that they were forced in to the porous sandstone from the sediments of later deposition.<sup>2</sup>

The structure of the Cretaceous on Peace river is described by F. H. McLearn as follows:

"The salient features of the foothill structure in this district are the long, low, east dips, of 10 degrees and less, and the steep west dips. The latter, affecting only 2 miles or less of section, and separated by 10 to 12 miles of low east dip, are probably related to incipient overthrusting. The structure as a whole represents the dying out of the effects of the Rocky Mountain overthrust. The border of the foothills is marked by an anticlinal structure pitching southward. This consists of a single, large anticline on Portage mountain and in the canyon and of two anticlines on Bull Head mountain.

"The transition from foothills to plains structure is very abrupt and takes place where the Portage Mountain anticline is succeeded by an area of gentle undulation and overthrust faulting extending as far east as the Gates. This includes a broad, low anticline at Hudson Hope and a small broken anticline at the Gates. From there to Cache creek there is a low east dip, under one-half degree, with a local west dip equally low near the mouth of Cache creek. Eastward to several miles below St. John the structure seems to be almost flat. Near the North Pine river and downstream the structure steepens with an east dip so as to bring the Dunvegan sandstone almost to river-level a few miles below the

<sup>1</sup> McLearn, F. H., Geol. Surv., Can., Sum. Rept., 1916.

<sup>2</sup> Huntley, L. G., Am. Inst., Min. Eng., Bull. 102, pp. 1345-1348.

mouth of Kiskatinaw river. From here to the bend at Montagneuse river the structure is flat. The section is east-west to this point. From the mouth of Montagneuse river southward a north-south section is cut and here a small south dip is revealed. Where the river turns east past Dunvegan an east-west section is again exposed and flat structure indicated. Beyond the mouth of Burnt river, the Peace turns to the northeast and so continues to Peace river. Here the strata rise downstream and the inclination near Peace river amounts to some 40 feet per mile to the south.

"From Peace river northward a north-south section is exposed and at first reveals a south dip of about 10 feet per mile. In the vicinity of the No. 2 well and extending to Tar island the structure is practically flat, although there is probably a slight rise of 1 or 2 feet per mile. Downstream from here there is a slight dip north of a few feet per mile to a point about 10 miles below the mouth of Cadotte river. Beyond this there is a gentle rise, and a final flattening out. The above structure applies to that observed above river-level. It is possible, however, owing to the thinning of the Loon River shales northward and the consequent rise of the limestone contact, that the lower strata below river-level, which would be reached by drilling, would be slightly tilted southward as compared with the overlying strata above river-level. This applies particularly to the section north of Tar island."

#### POTASH

Considerable interest has been manifested in the possible occurrence of potash in commercial quantities in the Mackenzie basin. The analyses of samples taken from brine springs and from waters rising from strata pierced in boring operations, as given on pages 126 and 127, are disappointing in this regard. The proportion of potassium is too small to be of commercial importance or to be indicative of the presence of beds of potassium minerals. Analyses of a sample of water rising from a depth of 268 feet, in a bore-hole put down at Vermilion chutes on Peace river, and of a sample taken from a natural spring at Sulphur point on the south shore of Great Slave lake, are equally disappointing.<sup>1</sup>

#### SALT

Numerous brine springs are found in the Mackenzie basin, from some of which salt is obtained for local consumption.

Rock salt or salt-bearing formation was reported to have been encountered in Palæozoic strata in two wells sunk by the Northern Alberta Exploration Company on Horse creek near McMurray. As the wells are only 155 feet apart there is a strange lack of agreement between the logs.<sup>2</sup>

	Well No. 1	Well No. 2
	Feet	Feet
Loose surface material.....	0- 17	0- 24
Limestone.....	17- 117	24- 124
Soapstone and limestone.....	117- 520	124- 590
Salt.....	520- 620	590- 690
Limestone.....	620- 635	690- 765
Salt.....	635- 740	765- 855
Limestone.....	740- 770	855- 935
Sandstone.....	770-1,475	935-1,406

<sup>1</sup> Camsell, C., Geol. Surv., Can., Sum. Rept., 1916.

<sup>2</sup> Mines Branch, Dept. of Mines, Can., "Report on the salt deposits of Canada and the salt industry," 1915, p. 84.

A boring for salt was made at McMurray by the Alberta Government in 1920. A calyx drill was used and the core carefully preserved. The drill struck the salt horizon at 648 feet from the surface and passed through 14 feet of transparent rock salt. Below this, rock salt and gypsum occur interspersed to a depth of 685½ feet where drilling ceased.<sup>1</sup>

<sup>2</sup>The springs that are economically the most important at the present day are those found at the base of the escarpment lying to the west and south of the forks of Salt river west of Slave river (Plate XIV). Although there are here four groups of springs, from each of which salt is deposited, there are only two from which it is being collected at present. About four tons of salt is collected annually for the use of the trading posts and missions of the Mackenzie River district.

The water of the springs flows into shallow circular basins, from which it trickles away through barren, salt-encrusted clay flats to the river. The basins are usually 15 or 20 feet in diameter and the bottoms are covered with salt deposited through the evaporation of the brine. In some cases hillocks of salt 12 or 15 feet in diameter and as much as 2 feet in height are formed at the springs.

At the time of Camsell's visit to these springs on August 26 and 27, 1916, the flow was rarely as much as 4 gallons per minute at any one spring, but is said to be considerably greater in the spring season.

Samples of brine taken from three localities were analysed by the Mines Branch, Department of Mines, Ottawa.

*No. 1 locality, Hudson Bay springs at the forks of Salt river: taken August 21, 1916.*

Contains in 1,000 parts by weight:

Ions.		Hypothetical combination	
Potassium.. . . . .	0.5	Potassium chloride.. . . . .	0.9
Sodium.. . . . .	101.5	Sodium chloride.. . . . .	258.0
Calcium.. . . . .	1.2	Calcium sulphate.. . . . .	4.1
Magnesium.. . . . .	0.2	Sodium sulphate.. . . . .	0.4
Chlorine.. . . . .	157.7	Magnesium chloride.. . . . .	0.8
Sulphuric acid (SO <sub>4</sub> ) .. . . .	3.2		
	264.2		264.2
Temperature of air on collection.. . . . .			62°F.
Temperature of brine.. . . . .			40°F.
Specific gravity at 65°F.. . . . .			1.204
Flow about 1½ gallons per minute from each of eight springs.			

<sup>1</sup> Personal communication from Dr. J. A. Allan, Department of Geology, University of Alberta.

<sup>2</sup> Camsell, C., Geol. Surv., Can., Sum. Rept., 1916.



No. 2 locality, Mission spring, about 6 miles south of the forks of Salt river: taken August 26, 1916.

Contains in 1,000 parts by weight.

Ions		Hypothetical combination	
Potassium.. . . . .	0.4	Potassium chloride . . . . .	0.8
Sodium.. . . . .	100.8	Sodium chloride.. . . . .	256.3
Calcium.. . . . .	1.2	Calcium sulphate.. . . . .	4.2
Magnesium.. . . . .	0.2	Sodium sulphate.. . . . .	0.2
Chlorine.. . . . .	156.6	Magnesium chloride.. . . . .	0.8
Sulphuric acid (SO <sub>4</sub> ).. . . . .	3.1		
	262.3		262.3

Temperature of air on collection.. . . . . 70°F.  
 Temperature of brine.. . . . . 35°F.  
 Specific gravity at 65°F.. . . . . 1.204  
 Flow about 3 gallons per minute.

No. 3 locality, Snake Mountain springs, about 2 miles east of Mission spring: taken August 29, 1916.

Contains in 1,000 parts by weight.

Ions		Hypothetical combination	
Potassium.. . . . .	0.4	Potassium chloride.. . . . .	0.8
Sodium.. . . . .	100.7	Sodium chloride.. . . . .	256.0
Calcium.. . . . .	1.2	Calcium sulphate.. . . . .	4.2
Magnesium.. . . . .	0.2	Sodium sulphate.. . . . .	0.2
Chlorine.. . . . .	156.4	Magnesium chloride.. . . . .	0.8
Sulphuric acid (SO <sub>4</sub> ).. . . . .	3.1		
	262.0		262.0

Temperature of air on collection.. . . . . 53°F.  
 Temperature of brine.. . . . . 40°F.  
 Specific gravity at 65°F.. . . . . 1.202  
 Flow about 4 to 5 gallons per minute.

In recalculating these analyses we find that sodium chloride constitutes in each sample over 97.6 per cent of the total solids. The percentage of dissolved matter in the brine, namely over 26 per cent, indicates practically a saturated solution of salt at that temperature.

The salt is probably derived from crystals of salt disseminated through the gypsum that is found in abundance in the escarpment. Its presence in at least some of the gypsum is shown by an efflorescence of common salt that appears on some specimens when exposed to the atmosphere. Salt-bearing gypsum of this nature occurs at Snake Mountain springs.

At La Saline, on Athabaska river, 28 miles below the mouth of the Clearwater, there are several mineral springs about half a mile east of the river on the edge of the valley. The deposits, which consist principally of calcareous tufa carrying a small amount of common salt, gypsum, and native sulphur, cover the face of the escarpment and have built up a cone 10 to 15 feet high and about 200 feet wide. Sulphuretted hydrogen gas escapes from the bank in several places. The water from the springs flows into a shallow lake, which is situated at the foot of the escarpment, and is surrounded by a clay flat partly bare and

partly covered with coarse grasses.<sup>1</sup> Following are the results of the analysis of a sample of water collected from this spring by McConnell.

<sup>2</sup>“Specific gravity, at 15.5°C., 1.052.

“Agreeably with the results of an analysis conducted by Mr. Wait, it contained, in 1,000 parts, by weight:

Potassium . . . . .	0.868
Sodium . . . . .	23.937
Calcium . . . . .	1.574
Magnesium . . . . .	0.496
Sulphuric acid (SO <sub>4</sub> ) . . . . .	4.702
Chlorine . . . . .	38.461
	<hr/>
Chlorine required, in addition to that found to satisfy bases	70.038
	0.056
	<hr/>
	70.094
“Hypothetical combination:	
Chloride of potassium . . . . .	1.655
“ sodium . . . . .	60.883
“ magnesium . . . . .	1.049
Sulphate of lime . . . . .	5.352
“ magnesia . . . . .	1.155
	<hr/>
	70.094
Total dissolved solid matter, by direct experiment, dried at 180° C. . . . .	69.616

“There was not enough of the water at the disposal of the operator to admit of his examining it for any of the more rarely occurring constituents.”

A copious saline spring bubbles up 100 feet from the west bank of Athabaska river, 2 miles above the mouth of Redclay creek, and feeds a considerable stream. Large quantities of sulphuretted hydrogen gas are given off.<sup>3</sup> An analysis of a sample of the water collected by Mr. McConnell gave the following results:

<sup>4</sup>“Specific gravity at 15.5°C., 1.012. An analysis, by Mr. Wait, showed it to contain, in 1,000 parts, by weight:

Potassium . . . . .	0.036
Sodium . . . . .	4.783
Calcium . . . . .	0.947
Magnesium . . . . .	0.122
Sulphuric acid (SO <sub>4</sub> ) . . . . .	2.759
Chlorine . . . . .	7.394
	<hr/>
Chlorine required, in addition to that found, to satisfy bases	16.041
	0.021
	<hr/>
	16.062
“Hypothetical combination:	
Chloride of potassium . . . . .	0.069
“ sodium . . . . .	12.165
Sulphate of lime . . . . .	3.220
“ magnesia . . . . .	0.608
	<hr/>
	16.062
Total dissolved solid matter, by direct experiment, dried at 180°C. . . . .	16.263

“The quantity of water at the disposal of the operator was too limited to allow of his examining it for any of the more rarely occurring constituents.”

<sup>1</sup>McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 35 D.

<sup>2</sup>Hoffmann, G. C., Geol. Surv., Can., Ann. Rept., vol. VI, p. 79 R.

<sup>3</sup>McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 36 D.

<sup>4</sup>Hoffmann, G. C., Geol. Surv., Can., Ann. Rept., vol. VI, p. 80 R.

Samples of brines were collected by S. C. Ells in the McMurray district as follows and analysed.

No. 1. Overflow from casing-head of No. 1 well, Athabaska Oils, Ltd., Athabaska river.

No. 2. Overflow from casing-head of "Salt of the Earth" well, sunk by A. von Hammerstein, on west bank Athabaska river, 1 mile north of MacKay.

No. 3. From largest spring at La Saline lake.

No. 4. Overflow from casing of well drilled by Fort McKay Oil and Asphalt Company, at La Saline (August, 1914).

*Results of Analyses of Brines<sup>1</sup>*

	No. 1	No. 2	No. 3	No. 4
	Parts per million	Parts per million	Parts per million	Parts per million
Ca.....	1638	1347	1821	3354
Mg.....	385	585	571	1021
K.....	296	336	496	192
Na.....	22988	76268	21184	84076
HCO <sub>3</sub> .....	469	372	530	36
CO <sub>3</sub> .....	none	none	none	none
Cl.....	36188	118636	39792	127960
SO <sub>4</sub> .....	4144	4920	4688	2956
Sp. gr. at 15.5° C.....	1.047	1.133	1.052	1.150

"A saline spring, emitting natural gas and carrying up small quantities of tar, occurs on the boulder beach at the upper end of Tar island" in Peace river, about 30 miles below the mouth of Smoky river, and a second spring is reported to occur on an island opposite the mouth of White Mud river.<sup>2</sup>

A long saline slough, 60 feet wide, occurs in sec. 25, tp. 106, 5th mer., and a saline river, 125 feet wide and with a slight current, crosses sec. 1, tp. 107.<sup>3</sup> Several springs of saline water, accompanied by sulphuretted hydrogen, bubble up close to the left bank of Christina river at a point about 12 miles up from its mouth.<sup>4</sup>

Numerous mineral springs occur along Clearwater river. The most notable group occurs on the north side about 4 miles below Cascade rapid. "Here the springs are very copious, issuing from the bank in a number of places, for a space of 300 yards in length. The largest single spring forms a small brook itself, and the addition of these and all the other mineral springs which flow in farther down, must increase considerably the soluble salts in the water of the whole river."<sup>5</sup> Five and a half quarts of water was taken from one spring and evaporated. A residue of 1.36 ounces (avoirdupois) of crude salt was obtained and from one-fifth to one-fourth more adhered to the kettle used in evaporating. The salt consisted of very large quantities of soda, chlorine, and sulphuric acid, large quantities of lime, magnesia, and carbonic acid, a small quantity of insoluble residue, and very small quantities of potash, alumina, and ferric oxide.<sup>6</sup>

<sup>1</sup> Mines Branch, Dept. of Mines, Can., Sum. Rept., 1914, p. 64.

<sup>2</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 49 D.

<sup>3</sup> Ponton, A. W., Dept. of the Interior, Top. Surv. Branch of Can., Ann. Rept. 1903-1909, p. 171.

<sup>4</sup> McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. V, p. 39 D.

<sup>5</sup> Bell, Robt., Geol. Surv., Can., Rept. of Prog., 1882-83-84, p. 26 CC.

<sup>6</sup> Adams, F. D., Geol. Surv., Can., Rept. of Prog., 1882-83-84, p. 18 MM.

Richardson states that a little below the rapid on Great Bear river "a small stream from the southward flows into the Bear Lake river, near whose sources the Indians procure an excellent common salt, which is deposited from the springs by spontaneous evaporation."<sup>1</sup> He also states that a thermal spring, much resembling sea-water in its saline contents, issues from the front of the cliff known as the Rock-by-the-river-side, and the fissure from which it flows is encrusted with crystallized gypsum. An analysis of the water showed that the chief salt was sulphate of magnesia.<sup>2</sup> Richardson was informed by Mr. McPherson that a salt spring, having a basin 15 feet in diameter, which is never dry, occurs on the top of Nahanni butte.<sup>3</sup> This butte stands at the junction of the Nahanni and Liard rivers. Mr. McConnell, who ascended it in 1887, did not find the spring, but says "a neighbouring mountain, however, showed a white patch on its steep side which is plainly due to the deposits of a mineral spring of some kind, and may be the one referred to."<sup>4</sup>

According to Petitot, salt occurs on mount Clark, and in this mountain two saline rivers, known as Big Salt and Little Salt rivers, take their rise.<sup>5</sup>

An outcrop of rock salt occurs on the northeast end of Bear rock and salt from this outcrop has been used by the mission at Norman. Rock salt has also been reported at Norman as occurring in the mountains to the west.

#### SILVER

The report that silver ore similar to the Cobalt ore had been discovered in the vicinity of Fond du Lac at the east end of lake Athabaska led to a great influx of prospectors into this region in 1915. The district was visited by Charles Camsell in the summer of 1915, but an examination of the prospects between Grease river and Camille bay failed to reveal any deposits of silver.<sup>6</sup>

A specimen weighing half an ounce and consisting of "an association of grey mica schist with a white subtranslucent quartz more or less thickly coated with hydrated peroxide of iron, carrying some coarsely crystalline galena" was assayed for Mr. E. Lyon, who reported having procured it from the south side of Great Slave lake about 40 miles east of Resolution. It was found to contain:

Gold.....none.  
Silver.....16·012 ounces to the ton of 2,000 pounds.

"The galena amounted to 41·2 per cent, by weight, of the whole; hence the same, freed from all gangue, would contain at the rate of 38·865 ounces of silver per ton of 2,000 pounds."<sup>7</sup>

<sup>1</sup> "Narrative of a second expedition to the shores of the polar sea in the years 1825, 1826, and 1827," by John Franklin. Appendix No. 1, p. 13.

<sup>2</sup> "Arctic searching expedition; a journal of a boat-voyage through Rupert's Land and the Arctic sea in search of the discovery ships under command of Sir John Franklin," vol. I, p. 183.

<sup>3</sup> "Arctic searching expedition; a journal of a boat-voyage through Rupert's Land and the Arctic sea in search of the discovery ships under command of Sir John Franklin," vol. II, p. 203.

<sup>4</sup> Geol. Surv., Can., Ann. Rept., vol. IV, p. 57 D.

<sup>5</sup> Bulletin de la Société de Géographie, 6th ser., vol. X, 1875, p. 162.

<sup>6</sup> Camsell, C., Geol. Surv., Can., Sum. Rept., 1915, p. 122.

<sup>7</sup> Hoffmann, G. C., Geol. Surv., Can., Ann. Rept., vol. XI, p. 33 R.

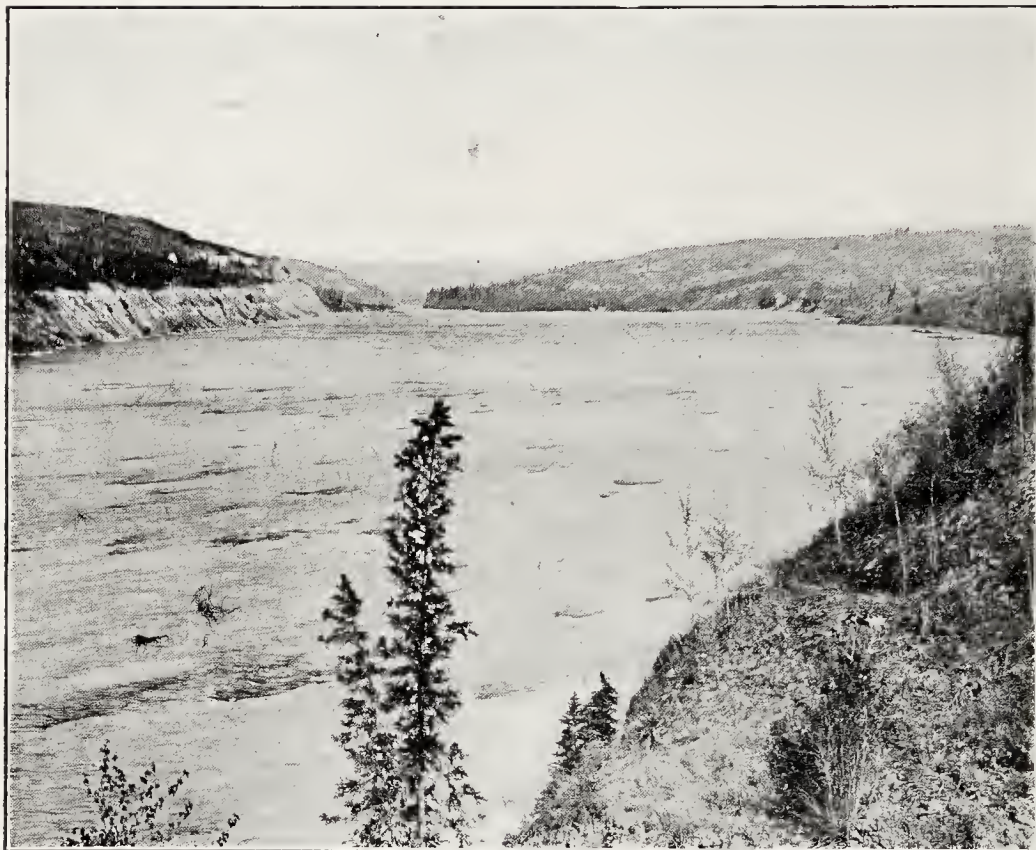
## PLATE II.



A Typical topography of the Laurentian plateau; near Chipewyan. (Pages 11, 12, 13.)



B. Reindeer mountains, east of the Mackenzie delta. (Page 22.)



A. Athabaska river near Grand rapids. (Page 22.)



B. Grand rapids, on Athabaska river. (Page 23.)

PLATE IV

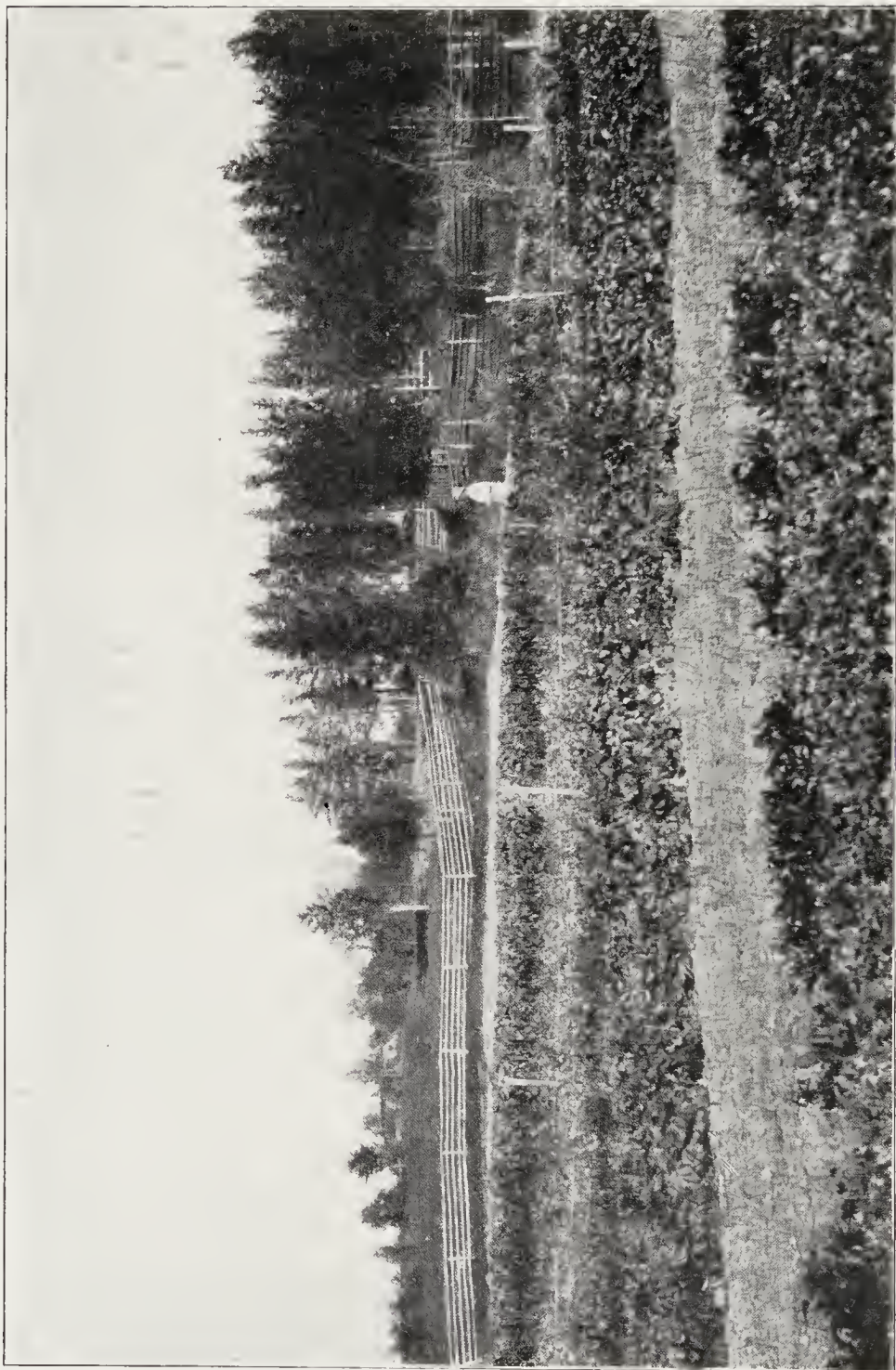


A. Lower falls on Hay river; height 46 feet. (Page 28.)



B. Falls on Tazin river.

PLATE V.



Garden at Fort Smith. (Page 40.)





Hay meadow on the salt plain west of Fort Smith. (Page 41.)

PLATE VII.



Buffalo range southwest of Fort Smith. (Page 45.)

## PLATE VIII.



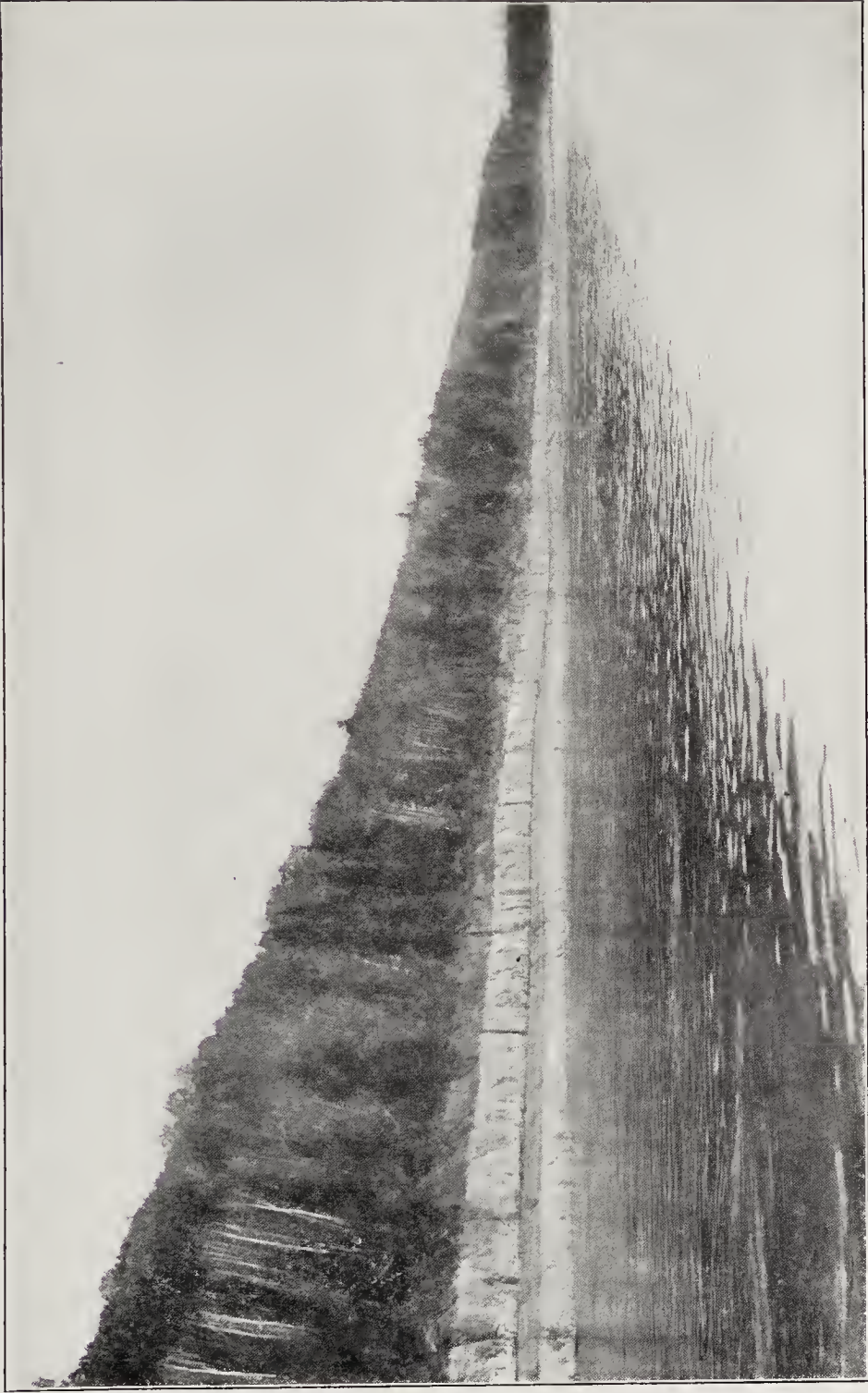
Forested country on Peace river below Little rapids. (Page 46.)



A. Chipewyan. Photograph by H. J. Bury, Dept. of Indian Affairs. (Page 54.)



B. Fort McPherson. (Page 54.)



Top of the Devonian limestone below McMurray on Athabaska river. (Page 66.)



A. Gorge between Alexandra falls and Lower falls on Hay river, looking down stream. (Page 65.)



B. The Ramparts, Mackenzie river. Photographed by H. J. Bury, Dept. of Indian Affairs. (Page 63.)

## PLATE XII.



A. Exposure of bituminous sand on the north side of Steepbank river,  $3\frac{1}{2}$  miles from its mouth, illustrating typical massive structure and cleavage of many of the high-grade deposits. (Pages 67 and 87.)



B. Exposure on the north side of Steepbank river, 2 miles from its mouth, showing low-grade and banded bituminous sand, overlying Devonian limestone. (Pages 67 and 87.)



Cliff of gypsum below Peace point, Peace river. (Page 106.)





Mission salt springs, southwest of Fort Smith. (Page 127.)



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